FILL WBZ TRENCH
DESIGN EVALUATION REPORT
GASCO/SILTRONIC

Prepared for
NW Natural

Prepared by
Anchor QEA, LLC
6650 SW Redwood Lane, Suite 333
Portland, Oregon 97224

April 8, 2015

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Expires
10/31/2015

April 8, 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

μg/L	microgram per liter
BTEX	benzene, toluene, ethylbenzene, and xylene
CDR	*Revised Groundwater Source Control Construction Design Report*
COP	City of Portland datum
DEQ	Oregon Department of Environmental Quality
DNAPL	dense nonaqueous phase liquid
EE/CA	*Engineering Evaluation/Cost Analysis*
FAMM	Fuel and Marine Marketing
FS	Feasibility Study
gpm	gallon per minute
GPR	ground penetrating radar
HC&C	hydraulic control and containment
HDD	horizontal directional drilling
HDPE	high-density polyethylene
HERA	*Human Health and Ecological Risk Assessment*
May 2011 Design Report	*Draft Groundwater Source Control Final Design Report*
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rule
ORS	Oregon Revised Statute
PAH	polycyclic aromatic hydrocarbon
PVC	polyvinyl chloride
RA	remedial alternative
Siltronic	Siltronic Corporation
Site	Gasco Site
USEPA	U.S. Environmental Protection Agency

USEPA Consent Order	2009 Administrative Settlement Agreement and Order in Consent
VOC	volatile organic compound
WBZ	Water-Bearing Zone

1 INTRODUCTION

1.1 Report Objective

The objective of this evaluation report is to use site data obtained as part of the recent Fill Water-Bearing Zone (WBZ) interceptor trench investigation work completed in 2014 together with existing site data to evaluate Fill WBZ groundwater containment alternatives and ultimately allow selection of a preferred alternative. The previously presumed approach is a trench system, but the November 2013 investigation work plan allowed evaluation of other options, as well as the evaluation and selection of an optimal location and construction approach for the Fill WBZ interceptor trench (Anchor QEA 2013a).

1.2 Project Background

As directed by the Oregon Department of Environmental Quality (DEQ), NW Natural has completed this design evaluation report for the Fill WBZ interceptor trench related to source control measures for the Gasco Site (Site) in Portland, Oregon.

This Fill WBZ interceptor trench design evaluation work is being completed consistent with the requirements of the following: 1) the Joint Order (DEQ Order No. ECVC-NWR-00-27 to NW Natural and Siltronic Corporation (Siltronic), dated October 4, 2000; DEQ 2000); and 2) the Voluntary Agreement (DEQ No. WMCVM-NWR-94-13, dated August 8, 1994, as amended July 19, 2006; DEQ 1994, 2006). The Site location is shown in Figure 1-1. On March 21, 2008, DEQ selected source control actions to address potential impacts to the Willamette River from manufactured gas plant and solvent contamination at the Gasco and Siltronic properties via the alluvial groundwater pathway. DEQ approved construction of the alluvial hydraulic control and containment (HC&C) portion of the design, which is completed, but did not direct immediate construction of source control for the Fill WBZ. However, control of Fill WBZ groundwater to the river using an interceptor trench was identified by DEQ as a needed element to address source control in its comments (September 22, 2011 and August 9, 2012 letters; DEQ 2011, 2012) on the *Draft Groundwater Source Control Final Design Report* (May 2011 Design Report; Anchor QEA 2011). This report evaluates the feasibility of six Fill WBZ groundwater source control methods and construction sequences to control fill groundwater discharge to the river.

NW Natural submitted the preliminary Fill WBZ Interceptor Trench Design Report and Drawings in Appendix A of the May 2011 Design Report (Anchor QEA 2011). That preliminary interceptor trench design was predicated on integrating the project with the riverbank remediation work being managed by the U.S. Environmental Protection Agency (USEPA) under a 2009 Administrative Settlement Agreement and Order on Consent (USEPA Consent Order). Several alternatives in the draft *Engineering Evaluation/Cost Analysis* (EE/CA) for the sediment remedy would impact the proposed location of the Fill WBZ interceptor trench. It therefore makes technical and common sense to integrate the Fill WBZ trench design with USEPA's eventual selection of a final riverbank remedy. DEQ did not accept key elements of the Fill WBZ trench design, including the length, alignment, construction sequence, and construction schedule proposed by NW Natural. DEQ requested that NW Natural develop this alternatives evaluation to consider designs that might make construction of the interceptor trench prior to riverbank work feasible.

1.3 Summary of Design History

The preliminary design for the interceptor trench was provided in the May 2011 Design Report (Anchor QEA 2011). DEQ refers to that report as the Revised Interim Design Report. Appendix A to the January 2012 *Revised Groundwater Source Control Construction Design Report* (CDR; Anchor QEA 2012a) contains the May 2011 design submittal. In the May 2011 Design Report, the Fill WBZ interceptor trench route is near the top of the riverbank and consists of a gravel-filled trench intersecting the entire vertical distance of the fill to about 1 foot into the underlying native soil layer, such that groundwater in the Fill WBZ is anticipated to collect in the trench. The underlying silt layer, which varies between elevations 5.0 to 0.0 foot City of Portland datum (COP), is presumed to provide enough lateral continuity and lower permeability that Fill WBZ groundwater can be efficiently captured by this system. The effectiveness of the conceptual design is, therefore, predicated upon the presence of a laterally continuous, lower-permeability layer that prevents groundwater from bypassing the trench and discharging to the river. The preliminary design also included a barrier that would be constructed on the river side of the trench to minimize capture of river water.

In addition, NW Natural stressed the importance of integrating any Fill WBZ trench work for DEQ with remedial approaches from USEPA for the sediment and riverbank project[1].

DEQ provided a compilation of agency comments on the preliminary Fill WBZ interceptor trench design to NW Natural on September 22, 2011 (DEQ 2011) and August 9, 2012 (DEQ 2012), following submittal of the May 2011 Design Report. As stated previously, DEQ did not accept the length, alignment, construction sequence, and construction schedule proposed by NW Natural in the May 2011 Design Report. The majority of DEQ comments focused on sequencing and trench location. In response to those comments, NW Natural prepared the revised *Fill WBZ Trench Investigation Work Plan*, provided in November 2013 (Anchor QEA 2013a). The objectives of the *Fill WBZ Trench Investigation Work Plan* were as follows: 1) collect data required for trench type and location evaluations; 2) evaluate the feasibility of constructing the Fill WBZ trench in sections; 3) evaluate potential shoring and construction requirements in the context of significantly variable groundwater elevations; and 4) evaluate other methods for Fill WBZ control.

Based on these evaluations, NW Natural may also recommend different or additional methods for fill groundwater control based upon new data (e.g., if alluvial system testing indicates operation of the HC&C system adequately dewaters the Fill WBZ in some locations). In addition, as USEPA selection of remedial alternatives for the riverbank advances, this information should be used to further inform alternative alignments or designs for the control of the Fill WBZ.

[1] Siltronic provided comment and review of the May 2011 Design Report prior to submittal to DEQ. As repeated in continuing correspondence to DEQ and the stakeholder team since then, Siltronic's approval of the Fill WBZ source control measure as described in the May 2011 Design Report was entirely contingent upon the reasonable and appropriate construction sequence described in the May 2011 Design Report (MFA 2011). Siltronic has never concurred with DEQ's selected sequence for implementation of the interceptor trench (MFA 2014).

2 SITE CONDITIONS

2.1 Groundwater Conditions

2.1.1 *Groundwater Elevation and Flow*

Seventeen shoreline Fill WBZ wells have been instrumented with pressure transducers to collect continuous water level elevations in the fill at 15-minute intervals. Water levels were recorded throughout 2014, and the data are maintained in a database.

Additional Fill WBZ wells (MW-39F, MW-40F, and MW-42F) were installed in November 2014 (see Figure 2-1). Appendix A presents the data report for the November 2014 field program. Installation of a fill monitoring well was planned at the location of MW-41U, but the fill in this area is shallow (approximately 6 feet) and dry, so an Upper Alluvium well was installed.

Groundwater surface elevations varied from elevation 32 feet COP in the wet season (MW-9-29) to a low of approximately elevation 7 feet COP (MW-4-35, MW-18-30, and MW-19-22) in the dry season in the historical Fill WBZ monitoring wells in the shoreline area. The geologic cross sections in Figure 2-2a through 2-2c show the high Fill WBZ water table measured in June 2009 and the low water table measured in August 2009. The wide variation in observed groundwater elevations is a function of the variation in fill permeability, seasonal recharge to the Fill WBZ, and seasonal river level changes. Seasonal changes in the groundwater elevation for the fill unit were typically 5 feet, but in some cases, groundwater levels fluctuated as much as 10 feet in a given year.

Groundwater levels in shoreline area Fill WBZ monitoring wells behave differently depending on the seasonal river stage at the time of measurement. For example, a Fill WBZ monitoring well may not respond to diurnal tidal river changes during a low river stage, but it may respond to tidal river changes at a higher river stage. This stage-dependent response was observed during the Segment 2 pump tests conducted in May and November 2010. In May, when river levels were seasonally high, hydrographs from Fill WBZ observation wells OW-7-17, OW-8-15, and OW-9-25 clearly showed river tidal fluctuations. During additional testing in November, when river levels were seasonally low, no tidal fluctuations were observed in these wells. In addition, water level data obtained during Phase 1 HC&C system testing were consistent with these observations. Groundwater elevation hydrographs for the shoreline area Fill WBZ monitoring wells were prepared for all periods during Phase 1 testing (October 2013 through December 2014), as shown in Appendix A figures.

As discussed in the *Groundwater Source Control Phase 1 Testing Data Summary and Analysis Report* (Anchor QEA 2015a), water levels in the Fill WBZ on NW Natural property showed very little response to HC&C system operation. A separate study of the Fill WBZ conducted by Siltronic showed water level declines attributed to operation of the HC&C system in some Fill WBZ wells (MFA 2015). However, the hydraulic connection between the Fill WBZ and Upper Alluvium WBZ cannot be assessed in detail until the HC&C system is pumped continuously for a period of months, rather than days.

2.1.2 *Groundwater Chemistry*

Groundwater was sampled and analyzed at 18 shoreline Fill WBZ monitoring wells, observation wells, and piezometers (MW-01-22, MW-02-32, MW-3-26MW-19-22, MW-21-12, MW-23-27, OW-1F, OW-2F, OW-5F, OW-7-17, OW-8-15, OW-9-25, OW-10F, PZ5-5, PZ6-5, PZ7-5, PZ8-5, and PZ9-5). Groundwater samples were analyzed for total, free, and available cyanide; metals; polycyclic aromatic hydrocarbons (PAHs); and volatile organic compounds (VOCs). Chemicals of interest concentrations in Fill WBZ groundwater in the shoreline area are quite variable. In general, all of the Fill WBZ monitoring wells in the shoreline area have groundwater with detected concentrations of total cyanide, PAHs, metals, and VOCs. Only four of the Fill WBZ monitoring wells have groundwater with detections of free cyanide (MW-1-22, MW-23-27, OW-9-25, and OW-5F). Mobile dense nonaqueous phase liquid (DNAPL) is generally not present in the Fill WBZ. Measurable DNAPL has only been encountered in one Fill WBZ monitoring well at MW-18-30.

2.1.3 *Contaminant Mass Flux*

The site MODFLOW model was used to determine average groundwater flows to the river during the calibration period of February/March 2014, which was selected due to the large number of precipitation events in that period. NW Natural is currently working with DEQ on the final calibration and verification of the model. Although some changes may be made during final model calibration and verification, additional changes are not expected to significantly change this contaminant mass flux analysis.

This analysis covers the portion of the river shoreline where the alluvial HC&C system has been constructed, which is coincident with the portion of the shoreline that DEQ is requesting implementation of Fill WBZ source control. During the February/March 2014 period, the average total groundwater flow to the river was 168 gallons per minute (gpm), and the average total flow from the Fill WBZ was 14 gpm, or 9 percent of the total groundwater flow.

The total average groundwater contaminant concentration was calculated from the shoreline area groundwater water quality dataset. The average total contaminant mass consists of the sum of average total cyanide; total PAH; total benzene, toluene, ethylbenzene, and xylene (BTEX); and total VOCs. The average total concentrations were calculated from the previous four sampling rounds of shoreline area wells screened in the Fill WBZ, Upper Alluvium WBZ, Lower Alluvium WBZ, and the Deep Lower Alluvium WBZ. This analysis included 68 samples from Fill WBZ monitoring wells, 116 samples from Upper Alluvium wells, 79 samples from Lower Alluvium wells, and 19 samples from Deep Lower Alluvium wells. The concentration averaging and calculation of total contaminant mass could be done in different ways, but this would not appreciably change the mass flux result subsequently discussed in this section.

The total average mass flux for each of these four WBZs was determined using the average total model derived flow from each WBZ matched with the average total contaminant mass for each WBZ. The mass flux determination showed that under non-pumping conditions during the model period, 15.4 pounds per day of contaminant mass would have discharged to the river from all four WBZs. Of that total, 0.3 pound per day came from the Fill WBZ, representing 1.9 percent of the total groundwater contaminant mass from the site. Although the Fill WBZ contributed 9 percent of the groundwater flow, the total contaminant concentrations in the Fill WBZ are substantially lower than the underlying alluvium. This means that the proportion of mass flux from the Fill WBZ (1.9 percent) is much smaller than its proportion of discharge (9 percent). As noted in Section 2.2, the currently operating HC&C system, therefore, already prevents more than 98 percent of the contaminant mass from the site groundwater from discharging to the river

This analysis shows that when the HC&C system operates as intended and produces full containment from the alluvial WBZ, as demonstrated during Phase 1 full system tests, it prevents more than 98 percent of the contaminant mass from discharging to the river.

2.2 Geotechnical Data

A compilation of subsurface data collected prior to the recent data gaps explorations is presented in the *Fill WBZ Trench Investigation Work Plan* (Anchor QEA 2013a). Appendix A presents the recently collected geotechnical data. Figure 2-1 presents previous explorations and the data gaps explorations (AQ-B8, MW-39F, MW-40F, MW-41U, and MW-42F). Figures 2-2 and 2-3 present interpreted subsurface geology along the alignment of the potential Fill WBZ source control system. Figures 2-2a, 2-2b, and 2-2c represent the riverbank adjacent to the

NW Natural and Siltronic properties, and Figure 2-3 represents the area adjacent to the U.S. Moorings property.

In addition to the data gaps explorations, data collected by Siltronic (for recently installed Fill WBZ monitoring wells) is included in this section.

Geotechnical conditions of the Fill soil are discussed in Sections 2.2.1 through 2.2.3 for the following three main areas:

- Along the top of the river bank at the NW Natural property
- Along the top of the river bank at the Siltronic property
- Adjacent to the U.S. Moorings property

Beneath the Fill unit is the Upper Alluvium unit. Alluvium soils just below the contact with the Fill generally consist of moist to wet, soft, brown to gray, low to high plasticity silt with a variable amount of sand. Along the U.S. Moorings property, the surficial alluvium generally consists of an upper layer of loose, damp to wet, multi-colored (brown, orange, gray, or white), fine to medium grained sand. There is commonly a silty soil layer at the surface of the alluvium. This silty soil layer is essentially the former ground surface that was present when dredge spoils and fill were placed at the site. This silty soil layer can act as a perching layer at the base of the Fill. In a recent investigation of the Fill WBZ, Siltronic found that where the upland property has been extended into the Willamette River, the silt layer represents former riverbed materials that were subject to the mixed erosional/depositional environment characteristic of this stretch of the river (MFA 2015). Data indicate that the silt is permeable and does allow slow infiltration of groundwater from the Fill WBZ to the underlying alluvium. The thickness of the silty soil layer is quite variable, from less than 1 foot to several feet (see Figures 2-2 and 2-3 for the layer's location).

2.2.1 *Top of Bank, NW Natural Property*

The Fill soil thickness and physical characteristics along the NW Natural property riverbank were evaluated with data from the newly advanced soil boring MW-39F and data from previously completed explorations. Figures 2-2a to 2-2b (cross section A-A') presents the interpreted geology and Fill thickness adjacent to the NW Natural property near the top of the riverbank. Fill thickness varied from 12 feet near GT-1 to 29 feet near GST-03. Fill thickness generally increases with increasing surface elevation at the site, which ranges from approximately 20 to 36 feet COP. As seen in Figures 2-2a to 2-2b, the contact elevation between the Fill unit and the Upper Alluvium unit is relatively flat, with a typical contact elevation range between 4 to 8 feet COP. The contact elevation lowers in the southeastern part of the NW Natural property up to the Siltronic property.

Fill soils generally consist of damp to wet, soft or loose, yellowish-brown to dark brown sand and silt (non-plastic to low-plasticity) with a variable amount of gravel. Occasional layers of hard or compacted soils were encountered in the upper 5 feet of the Fill unit. Concrete debris and other anthropogenic debris were present in the Fill unit in this area.

2.2.2 *Top of Bank, Siltronic Property*

Fill thickness and physical characteristics at the top of the river bank near the Siltronic property were evaluated with the data from newly advanced soil borings at MW-42F and AQ-B8 and data from previously completed explorations. Figure 2-2c (cross section A-A′) presents the interpreted geology and Fill thickness adjacent to the Siltronic property near the top of the riverbank. Fill soil thickness varied from 25 feet thick on the northwestern side of the Siltronic property to 40 feet thick on the southeastern side of the property near SIL-01. As seen in Figure 2-2c, the contact elevation between the Fill unit and the Upper Alluvium unit is relatively flat, with a typical contact elevation range between 2 to 8 feet COP.

Fill soils generally consisted of damp to wet, loose to medium dense, brown to dark brown or black, sand with a variable amount of gravel or silt. In general, the Fill unit in this area consisted of thick deposits of fine to medium grained sand with little to no fines. Occasional layers of hard or compacted soils were encountered in the upper 5 feet of the Fill unit. Concrete debris and other anthropogenic debris were generally not observed in the Fill in this area.

2.2.3 *Near U.S. Moorings Property*

The Fill soil thickness adjacent to the U.S. Moorings property was evaluated with soil borings MW-39F, MW-40F, and MW-41U. Figure 2-3, depicting cross section B-B′, presents the interpreted geology and Fill thickness adjacent to the U.S. Moorings property. As seen in Figure 2-3, the Fill soil thickness generally increases toward the river. Fill thickness varied from approximately 6 feet at MW-41U (furthest from the river) to approximately 26 feet at MW-40F, to 16 feet at MW-39F (the top of the riverbank). The contact elevation between the Fill and Upper Alluvium also generally deepened toward the river dropping from elevation 30 feet COP upland to 5 to 10 feet COP near the river with a low spot near MW-40F of elevation 5 feet COP.

Fill soils adjacent to the U.S. Moorings property generally consisted of soft to loose, brown to dark brown, silt or sand with a variable amount of gravel. Concrete debris and other anthropogenic debris were present in the Fill in this area.

3 IMPLEMENTABILITY CONSTRAINTS

A number of site features and related work will present a challenge to design and construction of the Fill WBZ source control system. Sections 3.1 through 3.3 focus on features related to utilities, structures, slopes, and other site elements. Section 3.4 focuses on the three other major remedial project elements that will impact the Fill WBZ source control project.

3.1 Buried Debris and Difficult Soils

Buried debris will hamper construction by impacting technologies that depend on driving or boring into the Fill unit. Debris will also slow down technologies that require excavation and may affect slurry levels if slurry is used for trench support.

Debris encountered in the recent data gaps investigation included metal wire, wood pulp, asphalt, concrete debris, brick, ballast rock, and organic debris. In addition to the debris encountered in the data gaps investigation, wood debris and chunks of wood, riprap, metal, and plastic debris have been encountered during previous explorations at the site.

The sample methods used for the data gaps and previous explorations used standard 4-inch to 6-inch-diameter drill tools, so the exact dimensions of debris encountered are unknown. Previous borings completed at the site have encountered hard drilling due to broken concrete, asphalt, and riprap, indicating that large-dimension debris (greater than 1 foot in dimension) should be expected.

Data gap investigations and explorations that have previously been completed indicate that some layers of the Fill soils have a high potential for caving in an open excavation. Soils encountered with potential for caving included loose (based on SPT-N values), gravelly sand, poorly graded sand with a low silt content, and sandy non-plastic silts. Seasonal groundwater influences will increase the potential for caving. As compared to soils encountered on the NW Natural property, Fill soils encountered on the Siltronic property tend to have a higher potential for caving due to a lower silt content and a higher sand content. This increased potential for caving reduces flexibility with respect to construction methods and equipment for some of the alternatives.

3.2 Variable Groundwater Elevations

Fill WBZ groundwater levels will primarily affect construction technologies that require excavation and/or shoring. As discussed in Section 2.1, groundwater levels within the Fill unit can vary significantly depending on the season and river stage. Fill WBZ source control construction will be substantially easier during low groundwater periods (due to the reduced need for dewatering and more stable soils) that typically occur in the fall. Construction technologies that require excavation should be avoided in the spring when river stages are higher.

3.3 Potential Impacts of Site Elements on Fill WBZ Source Control Alternatives

The shoreline of the Gasco and Siltronic properties has a number of structures and utilities that will complicate construction of the Fill WBZ source control system. Construction of the Fill WBZ source control system could also impact structures and utilities near the system. These site elements include the following:

- The HC&C system is installed along the entire shoreline and is comprised of extraction wells, monitoring wells, underground piping, underground communication lines, underground electrical lines, underground compressed air lines, and utility vaults. In addition, treated groundwater discharged from the treatment plant runs along the northern access ramp and discharges underwater at the pier into the Willamette River. Figure 3-1 shows the well, piping locations, and discharge outfall.
- Three Gasco property outfalls and one Siltronic property outfall (and associated piping back into the shoreline) are along the shoreline. Figure 3-1 identifies the outfall locations.
- The FAMM Lease Area has a number of structures near the shoreline, including the basin and aboveground storage tanks, the office building, and underground utilities (see Figure 3-1). The office building appears to have a shallow foundation system of concrete footings.
- There are two access ramps and associated product pipelines out to the dock structure.
- Siltronic (see Figure 3-1) operates equipment within its structures that is sensitive to vibrations. The Fab 1 building bump out is a slab on shallow footings. The crystal growing hall (in the plant's northwest corner) has a full basement that is approximately 15 feet below ground surface and also on shallow footings. Driving sheet piling or excavating through the Fill unit will generate vibrations that could cause disruptions to Siltronic's operations, especially if debris is encountered. A field study was conducted

in 2009 to determine the range of vibrations that could occur during installation of sheetpile, trenching, or other construction activities at the Site. The findings from that evaluation were reported in the *Vibration Study Data Report Gasco Siltronic Construction* (Anchor QEA et al. 2009). Based on findings from the study, Siltronic concluded that "a sheet pile barrier wall can be constructed along the GASCO shoreline up to the northwest boundary of the Siltronic property with appropriate selection of construction methods, vibration monitoring and warning alarms. Production was significantly impacted by vibration however solutions appear to be available to modify specific tool mounting or relocation of tools and a few office workers to accommodate the construction activities. Long-term effects of continuous vibration on sensitive measurement tools and connectors could not be evaluated. Construction of a sheet pile barrier wall adjacent to the operating wafering fabs also could not be evaluated. It is likely that additional testing will be necessary should it become necessary to install a barrier wall along the Siltronic shoreline." These findings indicate that there may be a similar need for additional vibration testing or control measures for various construction methods related to installation of a Fill WBZ trench close to the Siltronic fab building.

- Numerous other underground and aboveground utilities are present along the shoreline, including buried high and low voltage electrical lines, stormwater lines, access roads, and a fire water line.

Each of these potential issues needs to be considered when evaluating Fill WBZ source control systems.

3.4 Future Remedial Measures

This section focuses on the three other major project elements that will greatly impact both the design and construction of the Fill WBZ source control system (ongoing source control efforts, upland Feasibility Study [FS], and USEPA Gasco sediments project). Conversely, if constructed prematurely, the Fill WBZ source control system could impact the design and construction of those major remedial activities. Understanding these interactions is necessary when evaluating and selecting an alternative for controlling the Fill WBZ groundwater. Construction of the HC&C system began in September 2012, was substantially completed in 2013, and is currently operational. The system was designed and installed under DEQ oversight. The Gasco Sediments Cleanup Action remedy is a future remedial activity that is being evaluated under USEPA oversight with the goal of addressing impacted sediments within the Willamette River and contamination along the shoreline and up to the top of the river bank. Finally, an upland

FS will begin evaluating possible remedies to control upland sources as soon as DEQ provides final approval of the upland *Human Health and Ecological Risk Assessment* (HERA).

Integration of remedial measures for the Fill WBZ source control system, the HC&C system, the Gasco sediment remediation, and the upland remedial measures should assure long-term reliability of Fill WBZ controls or other remedial efforts, by:

- Recognizing that once one feature of a remedial measure is installed, that later design evaluations for other remedial measures will consider means to eliminate impact to that feature;
- Constructing an element of one measure concurrent with an element of another measure to avoid the need for removal and replacement at a later time; or
- Coordinating and sequencing key design elements of adjacent remedial measures to reduce future removal and replacement of one of the features

Specific potential impacts associated with the other three remedial measures to the Fill WBZ source control system, if appropriate integration is not conducted, are discussed in Sections 4.4.1 through 4.4.3.

3.4.1 *HC&C System*

A groundwater HC&C system has been constructed on the NW Natural and Siltronic-owned portions of the Site. The system is designed to prevent the discharge of contaminated groundwater from the alluvium to the river. The system consists of two major components, the groundwater HC&C system and the groundwater treatment system. The locations of the components of the system are shown in Figure 3-1. These components include 23 extraction wells, the well pipeline/control system, the Siltronic pretreatment plant, the NW Natural pretreatment plant, and the main treatment plant. Groundwater from seven of the extraction wells is pumped to the Siltronic pretreatment plant, and groundwater from 16 extraction wells is pumped to the NW Natural pretreatment plant and combined with effluent from the Siltronic pretreatment plant. The combined effluent from the NW Natural pretreatment plant is pumped to the main treatment plant, and then the treated effluent is pumped to the Willamette River through an outfall discharge that is permitted under a National Pollutant Discharge Elimination System (NPDES) permit.

The groundwater source control system has been in operation since September 2013. Since then, six Phase 1 system tests have been conducted, as described in the *Final Groundwater Source Control Extraction System Test Plan* (Anchor QEA 2013c). The tests have shown that the system successfully contains groundwater in the alluvial aquifers and prevents contaminated groundwater discharge to the river. As described in Section 2.1.3, the HC&C system prevents more than 98 percent of the total groundwater contaminant mass, including the contaminant mass from the Fill WBZ, from discharging to the river. A report that summarizes Phase 1 testing was submitted to DEQ on January 30, 2015 (Anchor QEA 2015a). The Phase 1 test report contains recommended operational protocols for a Phase 2 test of the system, which will occur in the winter/spring of 2015, subject to DEQ approval. During Phase 1, water levels in Fill WBZ monitoring wells were recorded to enable evaluation of the effects of pumping extraction wells in the underlying alluvium. As noted in the March 25, 2015 *Fill Water Bearing Zone Groundwater Evaluation* memorandum (MFA 2015), groundwater extraction during Phase 1 Step 6 in the underlying alluvium resulted in drawdown and dewatering of a portion of the Fill WBZ. The evaluation of potential drawdown effects in the Fill WBZ wells from HC&C operation will be continued during the Phase 2 testing.

Extraction wells within 10 to 20 feet of some Fill WBZ source control alternatives (e.g., a trench) will likely be destroyed or damaged during construction, requiring replacement. Plumbing and electrical components associated with the HC&C system will also likely require temporary disconnection and replacement. Figure 3-1 shows the location of the HC&C system components.

3.4.2 *Gasco Sediment and River Bank Remediation*

NW Natural submitted a draft EE/CA for the Gasco Sediments Cleanup Action (Anchor QEA 2012b) to USEPA in 2012. The EE/CA evaluated five remedial alternatives, each affecting the project area shoreline river bank to some degree. Three of the proposed alternatives would cut back into the shoreline to remove impacted, nearshore bank sediments or provide a stable slope upward from deep river cuts. Shoreline bank excavation could impact Fill WBZ control measures constructed near the shoreline. Figure 3-1 illustrates the estimated extent of impact to the shoreline river bank for the Gasco Sediments Cleanup Actions Remedial Alternatives 3, 4, and 5.

USEPA provided comments on the EE/CA (USEPA 2012) and indicated that preliminary design for the Gasco Sediment Site cannot effectively begin until the Portland Harbor Revised FS is completed. USEPA also provided a letter to NW Natural on June 13, 2014 indicating, "To reiterate, EPA feels the Portland Harbor Process has overtaken the need for a Final EE/CA for the Gasco Sediments Site. Hence, EPA is no longer requesting a Final EE/CA which obviates the need to resolve EPA's comments on the draft EE/CA….EPA intends to draw upon information in the draft Gasco EE/CA, as appropriate, during the FS revision process."

The current USEPA estimated completion date for the Portland Harbor revised FS is some time after the National Remedy Review Board meeting in November 2015.

Future shoreline excavations associated with Gasco sediment and river bank remediation could impact both the Fill WBZ source control system and the alluvial extraction wells (this issue is discussed in detail in Section 4). Figure 3-1 shows the location of the potential future shore excavations based on alternatives presented in the draft EE/CA. However, an alternative has not yet been selected by USEPA, and additional shoreline areas, currently identified in the EE/CA, could be impacted when USEPA selects an alternative.

3.4.3 *Upland Remedial Measures*

NW Natural plans to work on the upland FS in 2015. The sections of the Gasco upland HERA that address upland human and ecological receptor exposures to upland media have been conditionally approved by DEQ (2013), subject to NW Natural revising the HERA consistent with DEQ comments on the draft HERA (DEQ 2014a) and resolution of DEQ conditions (DEQ 2014b). The revised HERA report was submitted to DEQ on December 24, 2014, for final review and approval. In addition, DEQ requested submittal of soil and groundwater isocontour maps, which were submitted to DEQ on February 16, 2015 (Anchor QEA 2015b). Following DEQ review and approval of the revised HERA and supporting materials, it is anticipated that DEQ will allow scoping of the upland FS work plan to begin during the second quarter of 2015.

The FS will focus on a number of areas of the upland site, which include the following:

- Former Office Area
- Former Spent Oxide Area
- Fuel and Marine Marketing (FAMM) Lease Area
- Former Tar Pond Area
- Koppers Area

Work on an upland FS for the Siltronic property is anticipated in 2017, and discussions regarding coordination of this work are ongoing between Siltronic and NW Natural.

Potential remedial measures that will likely be evaluated as part of the upland FS include in situ and ex situ treatment, barrier installations, pavements or caps, and soil hotspot removal. A number of these potential measures could impact or be impacted by the Fill WBZ source control system. One example of a future upland remedy that could impact the Fill WBZ source control system is soil hotspot physical removal. Cut slopes from hotspot removal or shoring adjacent to removal areas could compromise the integrity of any Fill WBZ source control system and require replacement of compromised sections shortly after they are constructed.

4 WBZ FILL CONTROL METHOD EVALUATIONS

This section screens suitable technologies for controlling the Fill WBZ groundwater, develops six alternatives using the screened technologies, and finally, evaluates these alternatives considering different alignments or sequencing. Section 4.2 describes the alternatives and Section 4.3 evaluates these alternatives.

4.1 Technology Screening

A number of technologies were screened, including the following:

- Installing and screening vertical wells at the base of the Fill WBZ
- Paving concurrent with utilizing the existing HC&C system
- Installing an interceptor trench though the Fill WBZ
- Installing a horizontal interceptor drain at the base of the Fill WBZ

Each of these technologies is described in Sections 4.1.1 through 4.1.4 and screened prior to alternatives development in Section 4.2.

4.1.1 *Screen Vertical Wells at Base of Fill WBZ*

This technology would install wells along the crest of the slope (just behind the top of the slope) down through the Fill unit. The wells would be screened near the base of the Fill WBZ. Wells would be installed around surface obstructions, such as buildings and utilities, at spacing necessary to capture groundwater. Pumps within each well would pump the groundwater to a surface piping system. The groundwater would be collected, pumped, and treated by "piggybacking" onto the HC&C system.

The wells would likely have to be spaced very close together (i.e., 50 feet apart or less) to be effective when the water table is low. This required spacing of wells would likely be very costly. In addition, the collection system could still run dry in the fall during low water levels, which could cause problems with the pumping system.

For these reasons, Fill WBZ vertical wells are not carried forward in the evaluation.

4.1.2 *Upland Paving and HC&C System*

This technology involves paving the site in conjunction with operation of the existing HC&C system to control the Fill WBZ groundwater. Recharge to the upland Fill WBZ comes from infiltration of incident precipitation through the unpaved ground or areas not beneath a structure. Therefore, groundwater recharge in the Fill WBZ can be reduced by preventing infiltration of incident precipitation. It is likely that a component of the upland soil remedy at the site will include paving of surface soils that are not already paved or beneath a structure. If selected as an engineering control in the upland FS, paving would prevent direct exposure to site surface soil and reduce volatilization to outdoor air. For this report, it is assumed that once upland remediation is complete, all of the Site and much of the northern portion of the Siltronic site would be covered by existing pavement, beneath existing structures, or be paved as part of the upland remediation. Paving the site as part of an upland soil remedy would have the secondary benefit of reducing recharge to the Fill WBZ.

Operation of the alluvial groundwater HC&C system increases the downward vertical gradient from the Fill WBZ to the Upper Alluvium. Paving the site alone would reduce the amount of water in the Fill WBZ, and operating the HC&C system would increase downward flow from the Fill to the Upper Alluvium.

This technology is carried forward as a viable technology due to the technology's likely effectiveness at reducing the amount of groundwater in the Fill WBZ, ease of implementation, and relatively low cost.

4.1.3 *Install Interceptor Trench through Fill WBZ*

This technology involves excavating a trench through the full thickness of the Fill unit down to the Upper Alluvium and installing a perforated collection pipe at the base of the trench. A preliminary interceptor trench design was developed by Glynn Geotechnical Engineering (included as Appendix J to the CDR [Anchor QEA 2012]). Although this preliminary design provided one specific example, it was developed prior to the collection of DEQ-required additional Fill WBZ geotechnical and alignment data and is not constructible. Several alternatives involving this technology are discussed later in this report.

The general elements of an interceptor trench are described herein and would be applied to alternatives that utilize this technology. Design specifics for the trench would be developed as part of any final design process. Ideally, the trench installation would begin at the lowest points of the excavation and installation would precede upslope. The trench would be approximately 3 feet wide and extend to approximately 12 inches into the Upper Alluvium unit, which will vary along the alignment. This contact target would result in trench depths of 25 to 35 feet depending on the trench location. Roughly 20 feet of access would be needed shoreward of the trench alignment for equipment access. Utilities, wells, or structures within this 20-foot zone would likely need to be abandoned or removed and replaced.

The trench would need to be offset at least 10 feet from the top of bank for stability and construction access purposes. Preliminary geotechnical analysis was completed to assess the stability of the river bank assuming a 3-foot-wide trench is installed 10 feet back from the bank top. Gasco property bank slopes are generally flatter (2.5 horizontal to 1 vertical or flatter) than the Siltronic property slopes (up to 1 horizontal to 1 vertical in places). In general, interceptor trench construction along the Gasco property should not lower the factor of safety against slope movement. Interceptor trench construction along the steeper banks of the Siltronic property could cause some stability issues during construction. Any trenches adjacent to the Siltronic bank will need to be further evaluated during design. Siltronic has also expressed concern related to trench excavations adjacent to the steep Siltronic slopes (MFA 2013).

Trench installation next to structures (e.g., buildings, tanks, walls, and piers) needs to consider the foundation type when determining required offsets. Trenches installed next to structures with deep foundations can likely be installed closer to those structures than trenches next to structures with shallow foundations, such as portions of Fab 1 on Siltronic and the FAMM building. The age and the condition of the structures are also a factor relevant to determining allowable trench setbacks. For instance, the FAMM tanks near the shoreline were constructed more than 70 years ago. Research will need to be completed during design to assess the foundation type and condition if a trench alignment near these tanks is selected. Siltronic has also expressed concern related to trench excavations within 30 to 60 feet of building foundations and the affect they could have on building stability (MFA 2013). Finally, vibration tolerance of the Siltronic fab operations can affect necessary trench offset from the fab building (see Section 4.3 for discussion on vibrations and Siltronic's buildings).

The overall permeability of the constructed trench would target approximately 1 to 100 centimeters per second. The anticipated presence of debris in the full height of the Fill zone over much of the shoreline would likely severely limit the practicality of using sheetpile for shoring. Therefore, a type of slurry trench construction approach would be anticipated for support. A slurry trench provides temporary support of the trench walls during construction. Siltronic has expressed concerns over the use of a slurry support system on their property due to their belief that loss of slurry could occur with caving soil conditions (MFA 2013).

Non-structural sheeting would likely be installed along the river side to limit potential river water flow into the trench. The trench would be backfilled with pea-stone around an 8-inch-diameter perforated interceptor pipe at the bottom. Clean outs, force mains, and pump risers would also be required. A geotextile would be placed on the shoreward side of the excavation before the pea-stone is placed to provide separation between the stone and native soils. If construction segments are required, manholes would be installed at the segment boundaries to facilitate construction of future connections or provide sumps for collection of groundwater.

This technology is a proven effective technology; however, implementability will be very difficult (in some places possibly improbable), particularly in areas of heavy utilities and tight access around structures. Ideally, to improve construction ease, the trenches would be constructed in the late fall or winter when groundwater and river stages are the lowest. Installing the trench near the steeper banks on the Siltronic property may cause some bank stability concerns that need to be further evaluated during design. Installation near structures may not be practicable and would require further evaluation during design, as well. As discussed in Section 4.2, future remedial measures could require replacement of trench sections, which would affect implementability and cost. The cost of this technology is the highest of the other technologies screened, especially if future replacement is required.

This technology is carried forward primarily because of its known effectiveness.

4.1.4 *Install Horizontal Drill Interceptor Drain*

This technology involves horizontally drilling and installing multiple drains screened near the base of the Fill WBZ and aligned generally parallel to the shoreline. Horizontal wells are commonly installed using a mud-rotary method with specialized tooling that allows the driller to steer the drill underground. Transport of drill cuttings and hole support will occur using a biodegradable drilling mud. The drilling mud is collected and at the end of the job would be stabilized for landfill disposal.

The drill tools are pushed into the ground through a mud return pit located in front of the drill. The drill string consists of a drill bit designed to be steered underground, attached to a locating module containing the electronics that tell the driller where the drill bit is located. These devices are connected to the drill rods, which are engineered to bend while being rotated, allowing the bit to be advanced along the designed path. Depending on the rod diameter, the turning radius of the line would be 300 to 400 feet during drilling.

Drilling mud is supplied by a mud mixing system. The mud travels from the mixing system, down the inside of the drill rods, exiting into the borehole through nozzles in the drill bit. The mud travels up the borehole in the annular space between the drill tools and the borehole wall, exiting into the drill pit. The mud is pumped from the pit to a waste container or to a recycler where it is cleaned and reused if possible. There is a low potential that drilling mud, which is under pressure, could short circuit along buried debris or utility backfill and reach the river. The elevation of the horizontal drilled drain will be below any utilities that discharge to the river, and the distance between the drilled drain and the shoreline is wide enough that the chance of blowout to the river should be negligible. Mitigation measures to address this small risk could include a boom set up in the river and could be moved as the drill progresses.

Horizontal wells at the site would likely be installed using the double ended method. The double ended method is where the drill enters the ground at an angle and is directed along a curved path to a desired depth. To reach a depth of 25 to 30 feet common at the site, a run of 100 feet would be required. The drill bit is at or near level at this point and is drilled the desired length of screen. The drill bit is then directed to the surface where the bit is removed and the well materials are attached to the drill string behind a reamer. The well casing and screen is pulled into the borehole, the annular space is sealed and cemented, and the well is developed.

Once the screens are installed, the drilling mud would be broken down using an enzyme breaking solution. A hydrovac type system would be used to develop the wells.

Pumps would be installed in each well to remove Fill WBZ groundwater from the drain pipe. Groundwater from each well would be pumped to the existing HC&C pipeline and thereby transmitted to the HC&C treatment system. Each well would be constructed with cleanouts to enable future screen maintenance.

Horizontal wells installed using horizontal directional drilling (HDD) equipment have been used for many years and is a proven technology. One benefit of the technology over open trenching is that the technology would not require the removal and replacement of utilities, nor special shoring around buildings, because the technology can bore under such surface and near surface obstructions. The technology will also require less equipment and will generate less soil requiring handling and disposal. The drilled drain would be 4 inches in diameter, minimizing impacts to adjacent structures and slopes. Vibrations from this technology are expected to be minimal to not detectable. Multiple drains would be constructed, and the drains would overlap

50 to 100 feet for coverage. The technology should be able to drill through most debris—metal debris can cause issues. A pilot test of the technology would be recommended at the site to confirm that HDD can work in the anticipated Fill unit debris.

This technology was carried forward as a viable technology as a stand-alone alternative or as a substitute technology instead of a trench for a portion of the shoreline, where warranted.

4.2 Alternatives Development

Six alternatives were developed to control the Fill WBZ groundwater using the technologies carried forward from Section 4.1, which include the following:

- Pave substantial portions of the uplands in conjunction with operation of the existing HC&C extraction well system
- Use an interceptor trench near the slope crest and build it all at once
- Use an interceptor trench set back from the slope crest and build it all at once
- Use an interceptor trench near the slope crest but build it in segments
- Use an interceptor trench that is built in segments with portions near the slope crest and portions set back
- Install a horizontal drilled interceptor drain at the base of the Fill WBZ

4.2.1 *Alternative 1 – Upland Paving and HC&C System*

This alternative would use upland paving in combination with the existing HC&C system to control Fill WBZ groundwater. Paving the site alone could cut off recharge and dry up the Fill WBZ. Operating the HC&C system increases the downward vertical gradient between the Fill WBZ and the Upper Alluvium and would provide further ability to dry the Fill WBZ. For the purpose of this evaluation, it was assumed that the entire Site and the northern portion of the Siltronic site would be paved or beneath structures as part of the upland remediation. The total area to be confined beneath pavement or structures would be about 70 acres; the area requiring new paving would be about 50 acres of that 70 (see Figure 4-1 for the different areas). The exact amounts and areas of paving needed as part of this alternative would be determined during the design phase.

This alternative assumes the following:

- The currently unpaved areas or areas not beneath an existing structure, as shown in Figure 4-1 would be paved.
- The paving would be completed following agency approval of the upland FS as a component of the upland remediation of site soil.
- A stormwater collection system that ties in with the currently existing and newly paved areas would be constructed to comply with the NPDES stormwater management program. Grading, utility trenching, and working around existing utilities and structures will be more problematic on the Siltronic property. Paving around the electrical substation will also be challenging.
- The current HC&C system would continue.
- The design would include an annual inspection and maintenance program to assure the effectiveness of the system.

The site groundwater MODFLOW model was used to evaluate the effectiveness of this option. Using water level data from the February/March 2014 period, the effect of paving the areas shown in Figure 4-1 was evaluated. The model showed that groundwater flow to the river from the Fill WBZ would be reduced by about 60 percent by doing the additional paving. This finding is considered preliminary because the long-term drainage effects from operating the HC&C system require monitoring during the Phase 2 testing period.

Because it is expected that the site will be paved as part of the upland cleanup, this analysis assumes that the paving costs will be assigned to the upland remediation and not to source control. In addition, the costs for operating the HC&C system are not included in the cost estimate. Therefore, no cost was assigned to this alternative, although some costs may be directly associated with this alternative during the design of the upland remedy.

4.2.2 *Alternative 2 – Interceptor Trench Near Slope Crest (Built Continuously)*

Figure 4-2 shows the alignment of the interceptor trench for Alternative 2. This alignment is the alternative that is most similar to the preliminary alignment developed by Glynn Geotechnical Engineering (included as Appendix J to the CDR [Anchor QEA 2012]). It is important to note that DEQ rejected key elements from that trench design, including the length and alignment. This alternative assumes that an interceptor trench would be constructed along the entire alignment and built at one time.

Section 4.1.3 provides a description of the general trench design and construction approach. Specific elements for design and construction of this alternative include the following:

- The bottom elevation of the trench would range from 5 to 10 feet COP (as high as elevation 15 feet COP along the U.S. Moorings property).
- The total length of the alignment would be approximately 2,430 feet.
- Three manholes would be installed at the locations shown in Figure 4-2 to avoid the trench bottom having to be built as one very long continuous slope, which would be difficult. In addition, sumps may be required between manholes to allow shorter lengths of drainage grades.
- Approximately 6,900 cubic yards of material would be excavated from the alignment.
- The estimated duration to install the trench is 22 weeks.
- Installation of the proposed alignment would require at least seven HC&C extraction wells to be removed and replaced. In addition, the alignment would cross the HC&C plumbing and electrical corridor in two locations, which would require that those utilities be disconnected and then reconnected.
- The alignment would also cross the FAMM and Koppers product pipelines running out to the dock at two separate two locations.
- The alignment would also run close to the FAMM tanks in two locations and near the FAMM building. One section of the trench runs in a very narrow strip between the tanks and the top of the bank. The potential impacts to the tanks and structure will need to be assessed during design and possible mitigation measures (including further setback) developed. The alignment also is in the vicinity of the Siltronic buildings, which could impact building foundations or cause vibrations from excavations that could have negative impacts on fab operations (see MFA 2013 for Siltronic building foundation concerns). Design will need to consider foundation stability and potential vibrations. In addition, below- and above-ground utilities on the Siltronic site are likely to be adversely impacted.
- The alignment is approximately 10 feet off of the river bank on both the Gasco and Siltronic properties except for a few locations. The alignment adjacent to the Gasco bank is likely not an issue; the portion adjacent to the much steeper Siltronic portion will need to be further assessed during design (see MFA 2013 for Siltronic slope concerns).
- The alignment adjacent to the U.S. Moorings property will need to be installed immediately adjacent to and within a deep ravine, which will result in significant challenges.

- If not integrated into future Gasco sediment and river bank remediation with the shoreline trench alignment, up to 70 percent of the trench alignment could need to be replaced, based on the existing range of available alternatives (note, USEPA could eventually select alternatives that would have greater impacts on the trench). Additional impacts could also arise from upland-related remediation measures.

The detailed slopes, sumps, and alignments would need to be assessed as part of the design of this alternative. Additional geotechnical data are not anticipated to be required for this alignment.

The estimated cost to complete this alternative is $12.0 to $20.5 million. The lower end cost assumes cost to install the system as laid out in Figure 4-2 and replace any HC&C extraction wells damaged as part of the trench installation. The higher end estimate includes the costs of the lower end costs plus costs for replacing portions of the trench that would be damaged during the Gasco sediment remedy if Gasco Sediments Cleanup Actions Remedial Alternative 5 is selected. Table 4-1 summarizes the estimated costs. This cost range will be higher if replacement of Siltronic infrastructure is included, which could not be accurately estimated at this time.

4.2.3 *Alternative 3 – Interceptor Trench Further Back from Slope Crest (Built Continuously)*

This alternative assumes that an interceptor trench would be constructed along the entire alignment at once. Figure 4-3 shows the alignment of the interceptor trench for Alternative 3. The alignment for Alternative 3 is setback from the shoreline alignment for Alternative 2 to minimize potential future shoreline disturbances associated with the sediment and river bank remediation work under USEPA authority. However, there are some portions of this alignment that also would need integration with the river bank remedy, as discussed further in this section. The interceptor trench is located on the southwest side of the FAMM tanks to avoid potential future shoreline disturbances and the tank farm.

Section 4.1.3 provides a description of the general trench design and construction approach. Specific elements for design and construction of this alternative include the following:

- The bottom elevation of the trench would range from 5 to 10 feet COP (as high as elevation 15 feet COP along the U.S. Moorings property).

- The total length of the alignment would be approximately 2,570 feet.
- A manhole would be installed at the property boundary, as shown in Figure 4-3. In addition, sumps may be required between manholes to allow shorter lengths of drainage grades.
- Approximately 7,300 cubic yards of material would be excavated from the alignment.
- The estimated duration to install the trench is approximately 23 weeks.
- Installation of the proposed alignment would require at least two HC&C extraction wells to be removed and replaced. The alignment would also cross the FAMM and Koppers product pipelines to the pier in two locations.
- The alignment would run close to the FAMM tanks in two locations and near the FAMM building. Distances from the tanks are slightly larger than for Alternative 2. The potential impacts to the tanks and structure will need to be assessed during design and possible mitigation measures (including further setback) developed. The alignment near the Siltronic building was not offset from the riverbank because of concerns over building stability (MFA 2014). The alignment adjacent to the much steeper Siltronic portion will need to be further assessed during design (see MFA 2013 for Siltronic slope concerns). Final design will need to consider potential vibrations from the trench excavation. In addition, below- and above-ground utilities on the Siltronic site are likely to be adversely impacted.
- The alignment is offset a significant enough distance from the bank slopes on the Gasco property such that slope stability should not be a concern. The alignment adjacent to the much steeper Siltronic portion will need to be further assessed during design (see MFA 2013 for Siltronic slope concerns).
- This alignment would not intercept a substantial portion of Fill WBZ between the alignment and the river. As a result, a low permeability layer (e.g., paving) would need to be installed over approximately 4.7 acres of area between the trench and the crest of the slope to reduce surface water infiltration into the Fill WBZ (see Figure 4-3). Therefore, this alternative may not provide control of 100 percent of the Fill WBZ groundwater.
- If not integrated into the future Gasco sediment and river bank remediation work with the trench alignment, up to 7 percent of the trench alignment (all located on Siltronic) could need to be replaced, based on the existing range of available alternatives (note, USEPA could eventually select alternatives that would have greater impacts on the trench). Additional impacts could arise from upland-related remediation measures.

As part of design, the thickness of the Fill WBZ, and hence the interceptor trench depth, will need to be investigated along the new alignment near the FAMM tanks because data do not exist in this section of the alignment.

The estimated cost to complete this alternative is $13.1 to $14.0 million. The lower end cost assumes integration with upland and sediment remedies to eliminate potential future trench damage and replacement. The lower end cost assumes cost to install the system as laid out in Figure 4-3, replace any HC&C extraction wells damaged as part of the trench installation, and place asphalt between the offset trench and the slope crest. The higher end estimate includes the costs of the lower end costs plus costs for replacing portions of the trench that would be damaged during the Gasco sediment remedy if Gasco Sediments Cleanup Actions Remedial Alternative 5 is selected. Table 4-1 summarizes the estimated costs. This cost range will be higher if replacement of Siltronic infrastructure is included, which could not be accurately estimated at this time.

4.2.4 *Alternative 4 – Interceptor Trench Near Slope Crest (Built Segmentally)*

This alternative assumes that an interceptor trench would be constructed in segments, with some segments being built sooner than others, as described further in this section. Figure 4-4 shows the alignment of the interceptor trench for Alternative 4. The alignment is identical to that proposed for Alternative 2.

The alignment is broken into four subsections, labeled A through D in Figure 4-4. Generally, segments with the greatest potential for impact from the sediments and riverbank remedy, are built later, and segments with less potential for impact from this work are built sooner. However, all of the segments could require integration with the sediments and riverbank remedy, if some of the larger sediment alternatives are considered by USEPA (e.g., RA-5). The boundary of each subsection is described as follows:

- **Subsection A.** This subsection borders the U.S. Moorings property and the far northern portion of the shoreline. The southern boundary with Subsection B is near the northern edge of potential future shoreline disturbances associated with the Draft EE/CA Remedial Alternative 4 (RA-4). Roughly 45 percent of the alignment would fall within areas of potential future shoreline disturbances associated with the Draft EE/CA Remedial Alternative 5 (RA-5). This subsection, along with Subsection C, would be built first.

- **Subsection B.** This subsection extends from Subsection A running in front of the FAMM tank farm and extends past the access ramp to the pier. The southern boundary of this subsection is near the southern edge of potential future shoreline disturbances associated with the Draft EE/CA RA-4. This subsection, along with Subsection D, would be built at a later time either during or after the Gasco sediment remediation is completed, depending on the nature and extent of that remedy.
- **Subsection C.** This subsection extends from the Subsection B boundary to the Gasco/Siltronic property line. This subsection is generally along the Former Tar Pond shoreline. The entire length of this subsection is within the area of potential future shoreline disturbances of RA-5. This subsection, along with Subsection A, would be built first.
- **Subsection D.** This subsection is entirely on the Siltronic property. This subsection, along with Subsection B, would be built at a later time either during or after the Gasco sediment and river bank remedial measures are completed.

Section 4.1.3 provides a general description of the trench design and construction approach. Specific elements for design and construction for this alternative include the following:

- The bottom elevation of the trench would range from 5 to 10 feet COP (and as high as elevation 15 feet COP along the U.S. Moorings property).
- The total length of the alignment would be approximately 2,450 feet.
- Three manholes would be installed at the locations shown in Figure 4-4. Manholes would be located at the A/B, B/C, and C/D boundaries to allow future connections of the systems to the previous installed segments. In addition, sumps may be required between manholes to allow shorter lengths of drainage grades.
- Approximately 6,900 cubic yards of material would be excavated from the alignment.
- The estimated duration to install the trench is 24 weeks.
- Installation of the proposed alignment would require at least seven HC&C extraction wells to be removed and replaced. In addition, the alignment would cross the HC&C plumbing and electrical corridor in two locations, requiring replacement. The alignment would also cross the FAMM and Koppers product pipelines to the pier in two locations.
- The alignment would run close to the FAMM tanks in two locations and near the FAMM building. One section of the trench runs in a very narrow strip between the tanks and the top of the bank. The potential impacts to the tanks and structure will need to be assessed during design and possible mitigation measures (including further setback)

developed. The alignment also is in the vicinity of the Siltronic buildings, which could impact building foundations or cause vibrations from excavations that could have negative impacts on fab operations. Final design will need to consider potential vibrations. In addition, below- and above-ground utilities on the Siltronic site are likely to be adversely impacted.

- The alignment is approximately 10 feet off of the river bank on both the Gasco and Siltronic properties except for a few locations. The alignment adjacent to the Gasco bank is likely not an issue; the portion adjacent to the much steeper Siltronic portion will need to be further assessed during design (see MFA 2013 for Siltronic slope concerns).
- The alignment adjacent to the U.S. Moorings property will need to be installed immediately adjacent to and within a deep ravine, which will result in significant challenges.
- If not integrated into future Gasco sediment remediation work with the trench alignment in Segments A and C, up to 34 percent of the trench alignment could need to be replaced, based on the existing range of available alternatives (note, USEPA could eventually select alternatives that would have greater impacts on the trench). Additional impacts could arise from upland-related remediation measures.

Details of the slopes, sumps, and alignments would need to be assessed as part of design. Additional geotechnical data are not anticipated to be required due to the alignment.

The estimated cost to complete this alternative is $12.6 to $16.9 million. The lower end cost assumes integration with upland and sediment remedies to eliminate potential future trench damage and replacement. The lower end cost assumes cost to install the system as laid out in Figure 4-4 and replace any HC&C extraction wells damaged as part of the trench installation. The higher end estimate includes the costs of the lower end costs plus costs for replacing portions of the trench that would be damaged during the Gasco sediment remedy if Gasco Sediments Cleanup Actions Remedial Alternative 5 is selected. For estimating purposes, the costs for the later construction of Segments B and D assumed a 5-year delay. Table 4-1 summarizes the estimated costs. This cost range will be higher if replacement of Siltronic infrastructure is included, which could not be accurately estimated at this time.

4.2.5 *Alternative 5 – Interceptor Trench at Different Offsets from Slope Crest (Built Segmentally)*

This alternative assumes that an interceptor trench would be constructed in segments as described further in this section. Similar to Alternative 4, the general purpose of the segmentation is to minimize potential future impacts from the sediments and riverbank remedy to the trench alignment. Figure 4-5 shows the alignment of the interceptor trench for Alternative 5. Portions of the alignment are identical to that proposed for Alternative 2.

The alignment is broken into four subsections, labeled A through D in Figure 4-5. The boundary of each subsection is described as follows:

- **Subsection A.** This subsection borders the U.S. Moorings property and the far northern portion of the shoreline. The southern boundary with Subsection B is approximately the northern edge of the area of potential future shoreline disturbances associated with the Draft EE/CA Remedial Alternative 4 (RA-5). The alignment along this segment is the same as the alignment described for Alternative 3 (see Section 4.2.3), which is offset behind future expected shoreline disturbances associated with the sediment and river bank remedy (using the draft EE/CA Gasco Sediment remedial action alternatives as an approximate indication). This subsection, along with Subsection C, would be built first.
- **Subsection B.** This subsection is identical to Alternative 4 except for the added trench sections to connect the segment to Subsections A and C. This subsection, along with Subsection D, would be built at a later time once the Gasco sediment and river bank remedial measures are completed.
- **Subsection C.** This subsection extends from the Subsection B boundary to the Gasco/Siltronic property line. This subsection is generally along the Former Tar Pond shoreline. The alignment along this segment is the same as that described for Alternative 3 (see Section 4.2.3), which is offset behind expected future shoreline disturbances associated (based on the draft EE/CA). This subsection, along with Subsection A, would be built first.
- **Subsection D.** This subsection is identical to Alternative 4 except for the added trench section to connect the segment to Subsection C. This subsection, along with Subsection B, would be built at a later time once the Gasco sediment and river bank remedial measures are completed.

Section 4.1.3 provides a general description of the trench design and construction approach. Specific elements for design and construction of this alternative include the following:

- The bottom elevation of the trench would range from 5 to 10 feet COP (as high as elevation 15 feet COP along the U.S. Moorings property).
- The total length of the alignment would be approximately 2,570 feet.
- Three manholes would be installed at the locations shown in Figure 4-5. Manholes would be located at the A/B, B/C, and C/D boundaries to allow future connections of the systems to the previous installed segments. In addition, sumps may be required between manholes to allow shorter lengths of drainage grades.
- Approximately 7,200 cubic yards of material would be excavated from the alignment.
- The estimated duration to install the trench is 25 weeks.
- Installation of the proposed alignment would require at least ten HC&C extraction wells to be removed and replaced. In addition, the alignment would cross the HC&C plumbing and electrical corridor in three locations, requiring replacement. The alignment would also cross the FAMM and Koppers product pipelines to the pier in two locations.
- The alignment would run close to the FAMM tanks in two locations and near the FAMM building. One section of the trench runs in a very narrow strip between the tanks and the top of the bank. The potential impacts to the tanks and structure will need to be assessed during design and possible mitigation measures (including further setback) developed. The alignment also is in the vicinity of the Siltronic buildings, which could impact building foundations or cause vibrations from excavations that could have negative impacts on fab operations. Final design will need to consider potential vibrations. In addition, below- and above-ground utilities on the Siltronic site are likely to be adversely impacted.
- The alignment is approximately 10 feet off of the river bank on both the Gasco and Siltronic properties except for a few locations. The alignment adjacent to the Gasco bank is likely not an issue; the portion adjacent to the much steeper Siltronic portion will need to be further assessed during design (see MFA 2013 for Siltronic slope concerns).
- This alignment would not intercept a portion of Fill WBZ between the alignment and the river. As a result, a low permeability layer (e.g., paving) would need to be installed over approximately 1.5 acres of area between the trench and the crest of the slope to reduce surface water infiltration into the Fill WBZ. Therefore, this alternative may not provide control of 100 percent of the Fill WBZ groundwater.
- The proposed alignment should avoid areas of potential future Gasco sediment remediation, to the extent that can be estimated based on the draft EE/CA. Additional impacts could arise from upland-related remediation measures.

As part of design, the thickness of the Fill WBZ, and hence the interceptor trench depth, will need to be investigated for Subsections A and C because the alignment is significantly away from the slope to avoid potential future impacts. It is not anticipated that additional geotechnical and hydrogeologic data will be required along Subsections B and D.

The estimated cost to complete this alternative is $14.0 million. Costs were estimated to construct the interceptor trench as laid out in Figure 4-5, replace any extraction wells damaged as part of trench construction, and place asphalt between the offset trench location and the bank crest. This alternative assumed no costs to replace any trench length that would be damaged as part of future Gasco sediment remedial actions since the trench alignment is outside of the potential work. For estimating purposes, the costs for the later construction of Segments B and D assumed a 5-year delay. Table 4-1 summarizes the estimated costs. This cost range will be higher if replacement of Siltronic infrastructure is included, which could not be accurately estimated at this time.

4.2.6 *Alternative 6 – Horizontal Drilled Interceptor Drain*

A series of five horizontal wells would be installed for this alternative, as shown in Figure 4-6. The final location of the wells would be determined during design and after better understanding of process agreements that may be reached is obtained.

Section 4.1.4 provides a general description of the horizontal drain design and construction approach. A series of five horizontal drains would be installed, with each overlapping by approximately 50 to 100 feet as shown in Figure 4-6. Specific elements for design and construction for this alternative include the following:

- The invert elevation of the drain would range from 5 to 10 feet COP (and as high as elevation 15 feet COP along the U.S. Moorings property).
- Installation of the proposed alignment would require from two to four HC&C extraction wells to be removed and replaced.
- The first and last 100 feet of the drains would be inclined from the surface to obtain the horizontal portion of the drain 25 to 30 feet below grade. Each well segment would overlap an adjacent well segment by at least 50 feet.
- The finished drains would be 4 inches in diameter.

- An air actuated displacement pump would be installed in each of the five wells to remove Fill WBZ groundwater from the drain pipe. Compressed air is already available and installed along the HC&C alignment.
- Groundwater from each of the five wells would be pumped to the existing HC&C pipeline and thereby transmitted to the HC&C treatment system. A new vault box would be constructed where each of the five new pipelines are joined to the existing HC&C pipeline.
- Each well would be constructed with cleanouts to enable future screen maintenance.
- Approximately 10 to 20 cubic yards of material would be excavated from the alignment.
- Approximately 1.9 acres of area between the drain and the crest of the slope will need to have a low permeable layer (e.g., paving) to reduce surface water infiltration.
- Each well would take approximately 1 week to install. Once all of the wells are installed, another 2 weeks would be required to develop all of them. Another 7 weeks would be required to complete the plumbing of the wells to the HC&C system for a total duration of about 10 weeks.
- The horizontal interceptor drains would not have any potential slope impacts, would not interfere with site infrastructure or buildings, and is expected to have minimal vibration impacts, unlike the various trench alternatives previously discussed.
- If not integrated into future Gasco sediment and river bank remediation, up to 40 percent of the horizontal interceptor drain alignments might need to be replaced, based on the existing range of available EE/CA alternatives (note, USEPA could also eventually select alternatives with even greater impacts on the trench). Additional impacts could arise from future upland-related remediation measures.

Additional geotechnical data should not be required for this alternative based on currently available information; however, use of ground penetrating radar (GPR) or a similar technology would be recommended to confirm and optimize the alignment. An understanding of structural foundations in areas where the well crosses below a structure would be required. In addition, a pilot study would be required to better understand the system implementation and blowout potential. The pilot study would include installation of an HDD well and a pump test to determine capture effectiveness.

Alternative 6 could also be implemented in phases to minimize impacts from the river bank work. The HDD 1 and HDD 3 drain wells (see Figure 4-6) could be implemented in a later phase after the Gasco sediment and river bank remediation work is completed. Another possible option is to move the final alignment of the horizontal drains closer to the riverbank on the other side of the extraction wells. However, that change in the alignment would increase the need for integration with the future Gasco sediment and river bank remediation work.

The estimated cost to complete this alternative is $4.7 to $6.7 million. The lower end cost assumes integration with upland and sediment remedies to eliminate potential future horizontal interceptor drain damage and replacement. The lower end cost assumes cost to install the system as laid out in Figure 4-6, replace any HC&C extraction wells damaged as part of the drain installation, and place asphalt between the offset drain and the slope crest. The higher end estimate includes the costs of the lower end costs plus costs for replacing portions of the horizontal drain that would be damaged during the Gasco sediment remedy if Gasco Sediments Cleanup Actions Remedial Alternative 5 is selected. Table 4-1 summarizes the estimated costs.

4.3 Alternatives Evaluation

All of the alternatives are protective remedies. The remainder of this section differentiates between the alternatives.

The six alternatives were evaluated in accordance with DEQ guidance for conducting FSs (Oregon Administrative Rule [OAR] 340-122-0090(3)). Specifically, the following five balancing factors were used to evaluate the alternatives:

- **Effectiveness.** The alternatives will be assessed for their effectiveness in achieving protection by considering magnitude of risk from uncontained Fill WBZ groundwater, adequacy of engineering and institutional controls necessary to manage the uncontained groundwater, and time to achieve protection.
- **Long-term Reliability**. The alternatives will be assessed for their long-term reliability by considering reliability of the containment system, reliability of engineering controls necessary to manage uncontained groundwater, and nature, degree, and certainties of any necessary long-term management.
- **Implementability**. The alternatives will be assessed for the ease or difficulty of implementing the containment system considering practical, technical and legal difficulties and unknowns associated with the construction and implementation of the system, ability to monitor the effectiveness of the system, and availability of services, materials, and equipment for the system installation and operation.

- **Implementation Risk**. The alternatives will be assessed for the risk associated with implementing the remedial action by considering potential impacts to the community, workers, and environment during construction and operation and potential impacts to other site remedial systems, structures, and shorelines.
- **Cost**. The alternatives will be assessed for the reasonableness of costs considering capital costs for installation and repair of systems and structures impacted by construction, uncertainty of costs, and degree to which costs are proportionate to the system benefits. Costs should be within +50 percent to -30 percent of actual cost if the alternative were to be implemented.

Table 4-2 compares the six alternatives against each of these five criteria. Relative numerical scoring is also included in Table 4-2 to provide overall alternative comparisons. As discussed in the remainder of this section and summarized in Table 4-2, the differences between each alternative are short-term effectiveness versus long-term reliability, implementation, and cost.

Sections 4.3.1 through 4.3.5 provide a brief discussion of alternative comparisons against the five criteria.

4.3.1 *Effectiveness*

The differences between alternative effectiveness relates to the degree of engineering controls required for uncontained groundwater and delay in full implementation. The following is a comparison of the alternatives for effectiveness:

- Alternative 2 would be the most effective system because its proximity to the river bank would immediately control Fill groundwater sources and not require engineering measures (e.g., additional paving) to contain uncontrolled groundwater.
- Alternative 6 would also immediately control Fill groundwater sources. It would be a slightly less effective system than Alternative 2 because it requires 1.9 acres of asphalt as an engineering measure to control the wedge of groundwater located between the shoreline and offset location and may be slightly less effective at capturing groundwater than the trench. GPR, or similar technology, would likely be required along the proposed alignment to identify potential obstructions. An evaluation of building and tank foundations along the proposed alignments would be required to assess their potential impacts on drilling. A pilot study would be required to evaluate the effect of debris on drilling operations.

- Alternative 3 would be a slightly less effective system than Alternative 6 because it requires 4.7 acres of asphalt paving as an engineering measure to control the wedge of groundwater located between the shoreline and offset trench location. Like Alternatives 2 and 6, the system would immediately control Fill sources. Additional explorations would be required along the alignment near the FAMM tanks to understand subsurface conditions along the revised alignment.
- Alternative 4 would be a less effective system than Alternative 3 due to the delay in constructing Segments B and D at a later time.
- Alternative 5 would be a slightly less effective system than Alternative 4 because it requires 1.5 acres of asphalt paving as an engineering measure to control the wedge of groundwater located between the shoreline and offset trench locations in Segments B and D. Like Alternative 4, there would be a delay in constructing Segments B and D at a later time. Additional explorations would be required along the alignment near the FAMM tanks to understand subsurface conditions along the revised alignment.
- Alternative 1 is less effective than the others because modeling of this option indicates that discharge of Fill WBZ groundwater to the river would be reduced by 60 percent but not eliminated. It is important to note that the total contaminant mass flux captured by the source control system included in this alternative would be greater than 99 percent. Alternative 1 would also have a delay before full paving is complete, creating a short period where the alternative is not as effective as compared to the other alternatives.

4.3.2 *Long-term Reliability*

All alternatives utilize proven and reliable technologies. The difference between the alternatives with respect to long-term reliability is tied to the likelihood that future sediment and upland site remedial measures will impact the alternative's system. The effectiveness is at least temporarily reduced (during the time the trench is destroyed and something is reconstructed to replace it) to a greater degree for those alternatives that allow for less integration with the site remedial work. The following is a comparison of the alternatives for long-term reliability:

- Alternative 5 would likely be the least impacted by potential future Gasco sediment remediation work due to the offsets from the shoreline of Segments A and C and the sequencing of Segments B and D with future remedial work. Because Segments A and C are further inland, this alternative has more of a chance of being impacted by upland remedial measures.

- Alternative 3 would likely be more impacted by potential future Gasco sediment remediation work, with 7 percent of the alignment located within potential areas of shoreline excavation. However, because it is further inland, this alternative has more of a chance of being impacted by upland remedial measures.
- Alternative 4 would likely be significantly impacted by potential future Gasco sediment remediation work, with 34 percent of the alignment located within potential areas of shoreline excavation.
- Alternative 6 would likely be substantially impacted by potential future Gasco sediment remediation work, with 40 percent of the alignment located within potential areas of shoreline excavation. However, because parts of the alignment are further inland, this alternative has more of a chance of being impacted by upland remedial measures.
- Alternative 2 would likely be critically impacted by potential future Gasco sediment remediation work, with 71 percent of the alignment located within potential areas of shoreline excavation.
- Alternative 1 would likely be entirely destroyed by potential future Gasco sediment remediation work, with all of the HC&C extraction wells located within potential areas of shoreline excavation.

4.3.3 *Implementability*

All of the alternatives could be equally monitored for long-term effectiveness and performance. The differentiator between alternatives with regard to implementability is the ease of construction. The following is a comparison of the alternatives for implementability:

- Alternative 1 would be the most implementable of the alternatives because it already has the HC&C system installed and operational. Future paving would need to occur around a number of site features. Paving around the Puget Sound Energy substation could be challenging. No excavated material requiring handling and disposal is generated for this alternative.
- Alternative 6 would also be very implementable because it uses a technology that can easily work around surface structures and utilities, generates the smallest amount of cut material, and has minimal impacts on slopes or structures. Metal debris could impact drilling. Somewhat specialized equipment would be required to complete the installation.
- Alternatives 2 through 5 would be substantially more difficult to install. Excavating trenches around structures, utilities, and in tight confines will be difficult and possibly

infeasible in some areas. Structures and slopes could be impacted by nearby trenching, Siltronic operations could be impacted by vibrations, and excavation volumes around 7,000 cubic yards will require handling and disposal. Potential large debris could cause issues with maintaining slurry levels. The ravine along the U.S. Moorings property will result in additional implementation challenges for Alternatives 3 and 4. Connecting future segments to manholes for Alternatives 4 and 5 could be challenging.

4.3.4 *Implementation Risk*

Most of the alternatives will impact the existing HC&C system to some degree. During replacement of HC&C system components, the alluvial source control system will need to be shut down, reducing the short-term effectiveness of alluvial source control. As discussed in Section 3.1.3, the alluvial groundwater contributes 98 percent of the site groundwater contaminant mass flux to the river, which is currently contained by the HC&C system. Therefore, alternatives that require shutdown of the HC&C system during Fill WBZ containment construction will cause a significant increase in contaminant flux to the river that will continue until the HC&C system can be rebuilt and brought back online. This increase in contaminant flux seems to be an excessive risk to take for the installation of a Fill WBZ containment system that only represents 2 percent of the total contaminant mass flux to the river. The following is a comparison of the alternatives for implementation risk:

- Alternative 1 would have the lowest implementation risk because it will not impact any of the existing HC&C extraction wells, on-site structures, or slopes. Paving operations will present low risks to workers.
- Alternative 6 would only potentially impact four HC&C extraction wells during construction. Because of the technology, impacts to structures and slopes would be minimized. The technology also requires less equipment, labor, and excavation in confined areas, which presents a safer environment for the workers than Alternatives 2 through 5.
- Alternatives 2 and 4 would potentially impact seven HC&C extraction wells during construction. Potential impacts to Siltronic shoreline stability would need to be assessed during design. Potential impacts to Siltronic's Fab 1 building, the FAMM building, and FAMM tank foundations would need to be assessed during design. Vibrations from trench excavation could also impact Siltronic manufacturing operations. The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers than for Alternatives 1 and 6.

- Alternative 3 would potentially impact two HC&C extraction wells during construction. This alignment is the closest to Siltronic structures. Potential impacts to Siltronic's Fab 1 building, the FAMM building, and FAMM tank foundations would need to be assessed during design. Vibrations from trench excavation could also impact Siltronic operations. Because the alignment is pushed further upland, the potential to encounter impacted tar and DNAPL during construction increases. The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers than for Alternatives 1 and 6.
- Alternative 5 would have the most implementation risk. Potentially ten HC&C extraction wells could be impacted during construction. Potential impacts to the Siltronic shoreline stability would need to be assessed during design. Potential impacts to Siltronic's Fab 1 building, the FAMM building, and FAMM tank foundations would need to be assessed during design. Vibrations from trench excavation could also impact Siltronic operations. Because the alignment is pushed further upland in certain locations, the potential to encounter impacted tar and DNAPL during construction increases. The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers than for Alternatives 1 and 6.

4.3.5 *Cost*

Tables 4-1 and 4-2 present the range of anticipated costs for each alternative. The following is a cost comparison of the alternatives:

- Alternative 1 has no directly associated costs because the HC&C costs and the upland paving costs are anticipated to be part of other remedial measures. However, as stated in Section 4.2.1, there are likely some costs associated with this alternative, although those costs are difficult to determine prior to design.
- Alternative 6 is the lowest cost alternative of the remaining alternatives. The Alternative 6 estimated cost is 33 to 39 percent of the interceptor trench alternatives (Alternatives 2 through 5) estimated costs, assuming process agreements are implemented such that no impacts to the system alignments occur with Gasco sediment remediation. If Gasco sediment remediation is allowed to impact the alignments, the Alternative 6 estimated cost is 32 to 47 percent of the interceptor trench alternative (Alternatives 2 through 5) estimated costs.
- Alternatives 2 through 5 are the most expensive. They are similar in cost, assuming integration with potential future sediment and upland remedial measures. The order of

costs from low to high is Alternative 2, 4, 3, and then 5. If integration with sediment and upland remedial measures does not occur, Alternatives 2 and 4 become much more expensive than Alternatives 3 and 5 due to the likely trench replacement costs, in which case the order of costs from low to high is Alternatives 3, 5, 4, and 2. The costs for Alternatives 2 through 5 range from $12 to $20 million.

The mid-point from the range of costs for each alternative was used for cost comparison purposes and presented in Table 4-2. For scoring purposes in Table 4-2, the highest mid-range cost was set to 1, and although Alternative 1 is assumed to have no costs, its rating was set to 7 (a value of 10 was not used for Alternative 1 to account for potential uncertainty with its cost). All other alternatives were scaled proportionately to these values and rounded to the nearest 0.5.

When two or more remedial action alternatives are protective, Oregon Revised Statutes (ORS) 465.315(d)(E) requires DEQ to select the least expensive remedial action unless the additional cost of a more expensive alternative is justified by proportionately greater effectiveness, implementability, long-term reliability, or short-term implementation risk. Each of the alternatives evaluated in this report are protective when fully implemented. To the extent relevant, all alternatives also treat recovered groundwater through the existing groundwater treatment system. Alternative 1 is less effective than Alternatives 2 through 6. Alternative 6 reflects a better balance of effectiveness, long-term reliability, implementability, and short-term risk than Alternatives 2 through 5 and is much lower in cost. All alternatives will be more effective, have longer term reliability, be more implementable, have lower implementation risks and be far more cost effective if integrated with upland, river bank, and sediment remedies.

5 RECOMMENDED PATH FORWARD

The key to implementing a cost-effective and practicable Fill WBZ control alternative is integrating that alternative with the Gasco sediment and river bank work and the upland FS remedial work. Oregon's statutory remedy selection criteria strongly favor the identification of long-term integrated remedies that avoid short-term risk and are cost effective. Maintaining the effectiveness of the existing alluvial WBZ control system, which is removing 98 percent of the mass flux of contaminants from the site to the river, should be a primary goal of the source control program at Gasco. Long-term, cost-effective solutions that do not disrupt source control in the alluvial should be sought for lower risk sources, such as the Fill WBZ (which contributes less than 2 percent of the contaminant mass flux to the river).

The alternative that best meets the effectiveness, long-term reliability, implementability, short-term implementation risk, and cost criteria based on the Section 4 evaluation is Alternative 6, a horizontal interceptor drain system. Horizontal interceptor drain systems are a proven technology, which would be confirmed in a field pilot test. Horizontal interceptor drain systems would be highly implementable and represent a lower potential for interference with the future river and upland remedies.

The horizontal interceptor drain system would best meet the long-term reliability, implementability, short-term implementation risk, and cost criteria if integrated with the upland, riverbank, and sediment remedies. If DEQ concurs in NW Natural's recommendation for moving forward with the horizontal interceptor drain system alternatives, NW Natural would like to discuss the proposed schedule with DEQ. At a minimum, 180 days from DEQ direction to proceed are needed to submit 100 percent design documents. Upon DEQ approval of the final design package, it is anticipated that is will take 30 to 60 days to procure contractors and begin site work.

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TABLES

Table 4-1
Alternative Cost Summary

Alternative	Base Case[1]	Extraction Well Replacement			Additional Asphalt Pavement			Total Estimated Cost	Replacement Costs		Total Estimated Cost with Replacement
		No. of Wells	Cost per Well	Subtotal Cost	Acres of Pavement	Cost per Acre[2]	Subtotal Cost		Percentage of Alternative Replaced[3]	Subtotal Cost	
Alternative 1 – Upland Paving and HC&C System	$0	NA	NA	NA	NA	NA	NA	$0	NA	NA	$0
Alternative 2 – Interceptor Trench Near Slope Crest (Built Continuously)	$10,611,000	7	$200,000	$1,400,000	0.0	$350,000	$0	$12,000,000	71%	$8,500,000	$20,500,000
Alternative 3 – Interceptor Trench Further Back from Slope Crest (Built Continuously)	$11,074,000	2	$200,000	$400,000	4.7	$350,000	$1,645,000	$13,100,000	7%	$900,000	$14,000,000
Alternative 4 – Interceptor Trench Near Slope Crest (Built Segmentally)	$11,153,000	7	$200,000	$1,400,000	0.0	$350,000	$0	$12,600,000	34%	$4,300,000	$16,900,000
Alternative 5 – Interceptor Trench at Different Offsets from Slope Crest (Built Segmentally)	$11,540,000	10	$200,000	$2,000,000	1.5	$350,000	$525,000	$14,100,000	0%	$0	$14,100,000
Alternative 6 – Horizontal Drilled Interceptor Drain	$3,250,000	4	$200,000	$800,000	1.9	$350,000	$665,000	$4,700,000	42%	$2,000,000	$6,700,000

Notes:

1 = Interceptor trench construction for Alternatives 1 through 5; horizontal drilled interceptor drain construction for Alternative 6.

2 = Assumes 2 inches of asphalt over 4 inches of crushed rock in addition grubbing and subgrade improvements. Assumes site graded for sheet flow not requiring drainage piping.

3 = Estimated replacement based on current Gasco Sediment Alternatives. USEPA could eventually select alternatives that would have greater impacts on the trench. Does not consider potential replacement needed for upland remedial measures.

NA = not applicable

Table 4-2
Fill WBZ Source Control Alternatives Comparison

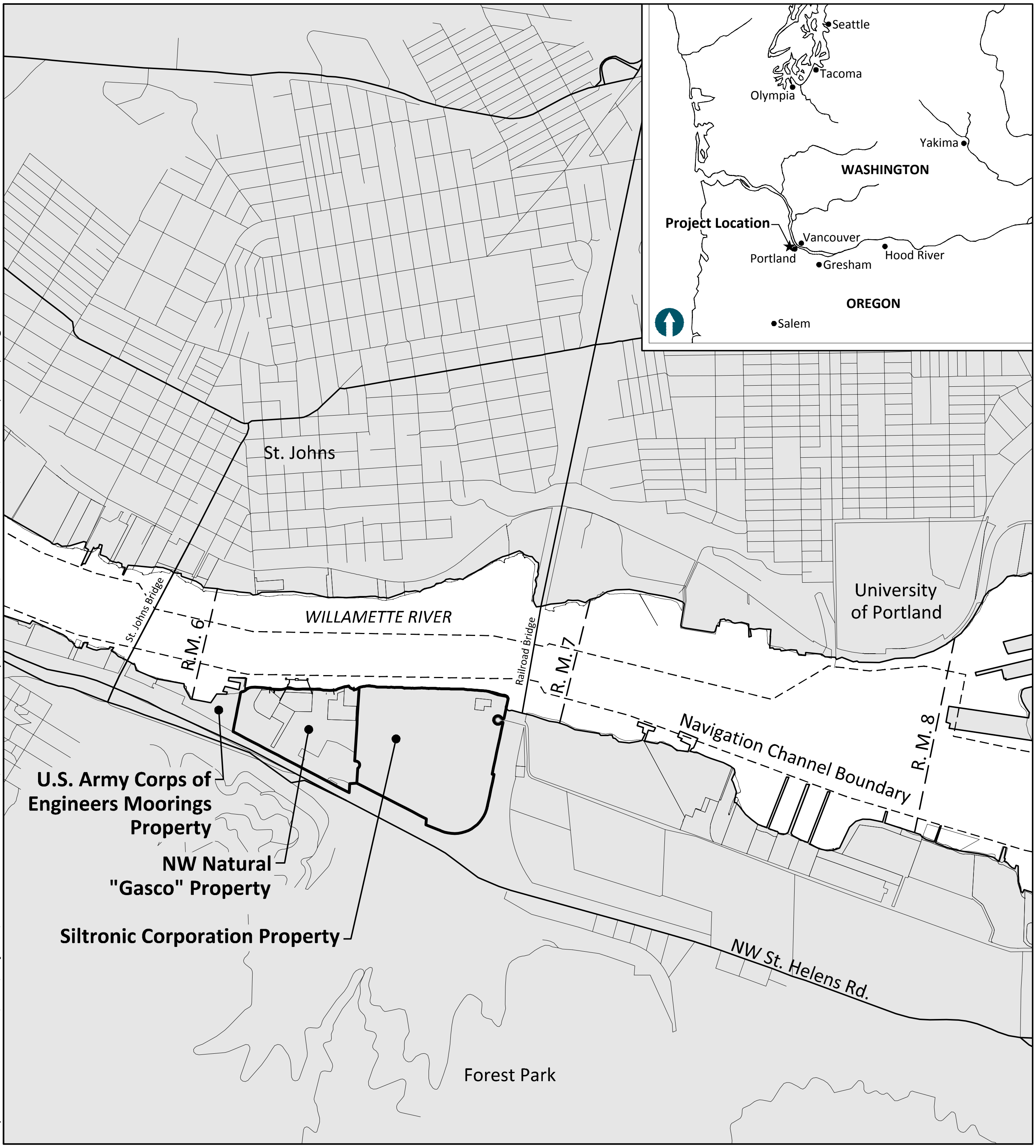
Alternative	Effectiveness	Long-Term Reliability	Implementability	Implementation Risk	Cost[1]	Total Score[2]
Alternative 1 – Upland Paving and HC&C System	**SCORE: 1** • Groundwater flow modeling shows that paving the site would reduce Fill WBZ discharge to the river by about 60 percent, with 40 percent of the flow continuing to discharge to the river. • Slight delay in full implementation because the site paving would not occur until the upland remedies are implemented which will impact effectiveness somewhat. • Continued monitoring during Phase 2 testing may show that the HC&C system would further reduce the Fill WBZ discharge to the river.	**SCORE: 4** • The alternative uses a reliable technology. • All of the HC&C extraction wells could be impacted by future sediment work.	**SCORE: 9.5** • The HC&C system is currently in place and operational. • Paving would need to occur around a number of site features. Paving likely required as part of the upland remediation. • No excavated material requiring handling, and disposal is generated for this alternative.	**SCORE: 10** • Construction will not impact the existing HC&C system, structures, or slopes. • Paving operations will present low risks to workers.	**SCORE: 7.0** $0	**31.5**
Alternative 2 – Interceptor Trench Near Slope Crest (Built Continuously)	**SCORE: 10** • The system would be effective controlling all Fill groundwater the soonest. • Does not require additional engineering measures to contain uncontrolled groundwater.	**SCORE: 7** • The alternative uses a reliable technology. • Removal and replacement of up to 71 percent of the system at a later time associated with the future Gasco sediment remediation work could impact the reliability, especially at connection points.	**SCORE: 6** • Approximately 6,900 cubic yards of excavated material will require handling and disposal. • The central portion of the alignment around the FAMM tanks and piping would be very difficult to install due to heavy utilities, the HC&C system, and structures. • Potential large Fill debris could cause issues with maintaining slurry levels. • The ravine along the U.S. Moorings property will be challenging.	**SCORE: 6** • Trench installation will likely require the abandonment and reinstallation of seven HC&C extraction wells and crossing the piping/electrical corridor twice. • Potential Siltronic riverbank stability impacts would need to be evaluated in detail as part of final design. • Effects of the trench on FAMM tanks and buildings foundations would need to be assessed as part of final design. • Installation vibrations near the Siltronic building could cause issues with manufacturing. • The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers.	**SCORE: 1.0** $12.0 million to $20.5 million	**30**
Alternative 3 – Interceptor Trench Further Back from Slope Crest (Built Continuously)	**SCORE: 9** • The system would be effective controlling most Fill groundwater soonest. • A large wedge of Fill between the trench and shoreline not captured by the trench. A low permeability surface, likely pavement, would be required between the trench alignment and the riverbank slope crest (approximately 4.7 acres). • Additional explorations would be required along the alignment near the FAMM tanks to understand subsurface conditions along the revised alignment	**SCORE: 8.5** • The alternative uses a reliable technology. • Removal and replacement of up to 7 percent of the system at a later time associated with the future Gasco sediment remediation work could impact the effectiveness, especially at connection points. • Pushing the alignment further inland could cause complications and interference from future upland remedies (e.g., if hotspot areas of the Former Tar Pond Area needs to be removed).	**SCORE: 6** • Approximately 7,300 cubic yards of excavated material will require handling and disposal. • The central portion of the alignment behind the FAMM tanks would be very difficult to install due to the presence of heavy utilities. • Potential large Fill debris could cause issues with maintaining slurry levels.	**SCORE: 5** • Trench installation will likely require the abandonment and reinstallation of two HC&C extraction wells. • Effects of the trench on FAMM tanks and buildings foundations, as well as the Siltronic building foundation, would need to be assessed as part of final design. • Pushing the alignment further inland could increase the potential to encounter impacted tar and DNAPL during construction increases. • Alignment closest to Siltronic's building—installation vibrations near the building could cause issues with manufacturing. • The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers.	**SCORE: 1.0** $13.1 million to $14.0 million	**29.5**

Table 4-2
Fill WBZ Source Control Alternatives Comparison

Alternative	Effectiveness	Long-Term Reliability	Implementability	Implementation Risk	Cost[1]	Total Score[2]
Alternative 4 – Interceptor Trench Near Slope Crest (Built Segmentally)	**SCORE: 8** • Does not require additional engineering measures to contain uncontrolled groundwater. • Slight delay in effectiveness because the Segment B and D trenches would not be installed until later. • Effective once all the trenches are installed.	**SCORE: 8** • The alternative uses a reliable technology. • Removal and replacement of up to 34 percent of the system at a later time associated with the future Gasco sediment remediation work could impact the effectiveness, especially at connection points.	**SCORE: 5** • Approximately 6,900 cubic yards of excavated material will require handling and disposal • The central portion of the alignment around the FAMM tanks and piping would be very difficult to install due to heavy utilities, the HC&C system, and structures. • Installing future segments (B and D) and connecting to existing segments (A and C) at manholes could be challenging. • Potential large Fill debris could cause issues with maintaining slurry levels. • The ravine along the U.S. Moorings property will be challenging.	**SCORE: 6** • Trench installation will likely require the abandonment and reinstallation of seven HC&C extraction wells and crossing the piping/electrical corridor twice. • The extensive labor, equipment and excavation work in tight confines will present higher risk to workers. • Potential Siltronic riverbank stability impacts would need to be evaluated in detail as part of final design. • Effects of the trench on FAMM tanks and buildings foundations would need to be assessed as part of final design. • Installation vibrations near the Siltronic building could cause issues with manufacturing.	**SCORE: 1.0** $12.6 million to $16.9 million	**28.0**
Alternative 5 – Interceptor Trench at Different Offsets from Slope Crest (Built Segmentally)	**SCORE: 7.5** • Slight delay in effectiveness because the Segment B and D trenches would not be installed until later. • Small wedge of Fill between the trench and shoreline not captured by trench. A low permeability surface, likely pavement, would be required between the trench alignment and the riverbank slope crest (approximately 1.5 acres). • Effective once all the trenches are installed. • Additional explorations would be required along the alignment near the FAMM tanks to understand subsurface conditions along the revised alignment.	**SCORE: 9** • The alternative uses a reliable technology. • Future Gasco sediment remediation would likely not impact the interceptor trench. • Pushing the alignment further inland could cause complications and interference from future upland remedies (e.g., if hotspot areas of the Former Tar Pond Area needs to be removed).	**SCORE: 5** • Approximately 7,200 cubic yards of excavated material will require handling and disposal • The central portion of the alignment around the FAMM tanks and piping would be very difficult to install due to heavy utilities, the HC&C system, and structures. • Installing future segments (B and D) and connecting to existing segments (A and C) at manholes could be challenging. • Potential large Fill debris could cause issues with maintaining slurry levels.	**SCORE: 4** • Trench installation will likely require the abandonment and reinstallation of ten HC&C extraction wells and crossing the piping/electrical corridor three times. • Pushing the alignment further inland could increase the potential to encountered impacted tar and DNAPL during construction increases. • Potential Siltronic riverbank stability impacts would need to be evaluated in detail as part of final design. • Effects of the trench on FAMM tanks and buildings foundations would need to be assessed as part of final design. • Installation vibrations near the Siltronic building could cause issues with manufacturing. • The extensive labor, equipment, and excavation work in tight confines will present higher risk to workers.	**SCORE: 1.0** $14.1 million	**26.5**
Alternative 6 – Horizontal Drilled Interceptor Drain	**SCORE: 9.5** • The system may be very slightly less effective than an interceptor trench system at capturing Fill groundwater. This would be checked during the pilot test. • Small wedge of Fill between the trench and shoreline not captured by trench. A low permeability surface, likely pavement, would be required between the trench alignment and the riverbank slope crest (approximately 1.9 acres). • GPR, or similar technology, would likely be required along the proposed alignment to identify potential obstruction. • An evaluation of building and tank foundations along the proposed alignments would be required to assess their potential impacts on drilling.	**SCORE: 7.5** • The alternative uses a reliable technology. • Removal and replacement of up to 40 percent of the system at a later time associated with the future Gasco sediment remediation work could impact the effectiveness. • Because the alignment is somewhat further inland, it could have complications and interference from future upland remedies (e.g., if hotspot areas of the Former Tar Pond Area needs to be removed).	**SCORE: 9** • A pilot study to evaluate potential construction issues would be required. • Approximately 20 cubic yards of excavated material will require handling and disposal • A minimal volume of material would be required for disposal compared to the trench alternatives. • Potential metallic Fill debris could cause issues with horizontal drain drilling. • Somewhat specialized equipment would be required to install the drains.	**SCORE: 9.5** • Drilling will likely require the abandonment and reinstallation of two to four HC&C extraction wells. • Significantly easier to work around surface obstruction, such as buildings, tanks, and utilities. • There would be minimal vibrations around the Siltronic building than with excavations. • Should not cause bank stability issues during installation. • The technology requires less equipment, labor, and excavation in confined areas, presenting a safer environment for the workers.	**SCORE: 3.0** $4.7 million to $6.7 million	**38.5**

Notes:
1 = Low end cost is for installation of system. High end costs includes system installation plus potential replacement of the portion of the system impacted by Gasco sediment remediation only (does not include Upland impacts or potentially larger Gasco sediment impacts)
2 = Individual scores are based on 10 being perfect or best score. Cost score is relative to the highest cost set to 1.0. Score column is summation of five criteria scores.
DNAPL = dense nonaqueous phase liquid
FAMM = Fuel and Marine Marketing
GPR = ground penetrating radar
HC&C = hydraulic control and containment
WBZ = Water-Bearing Zone

FIGURES

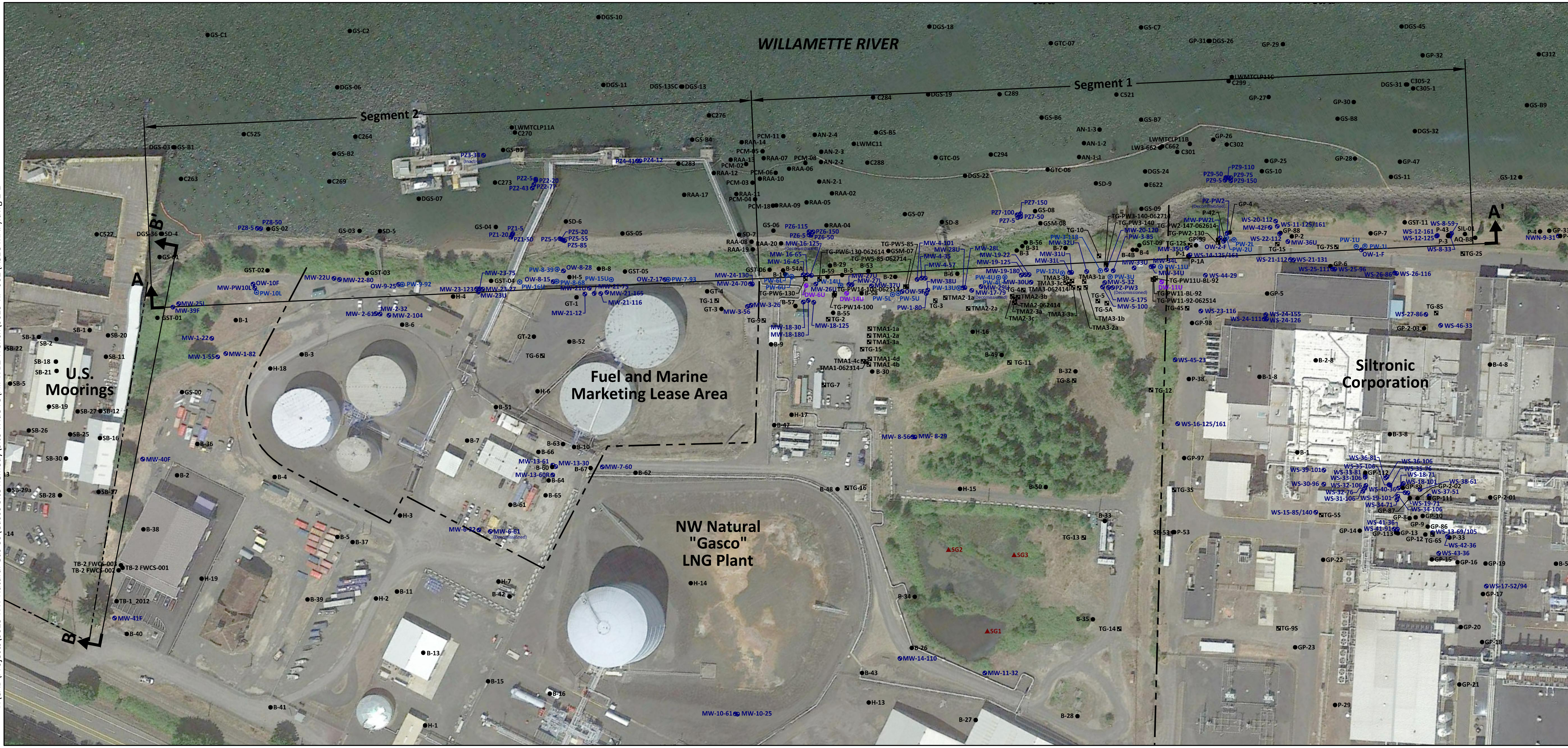


NOTE: All locations are approximate.

Apr 07, 2015 11:57am mpratschner T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-001 (VMAP).dwg 1-1

ANCHOR QEA

Figure 1-1
Vicinity Map
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



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Apr 07, 2015 12:09pm mpratschner

HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

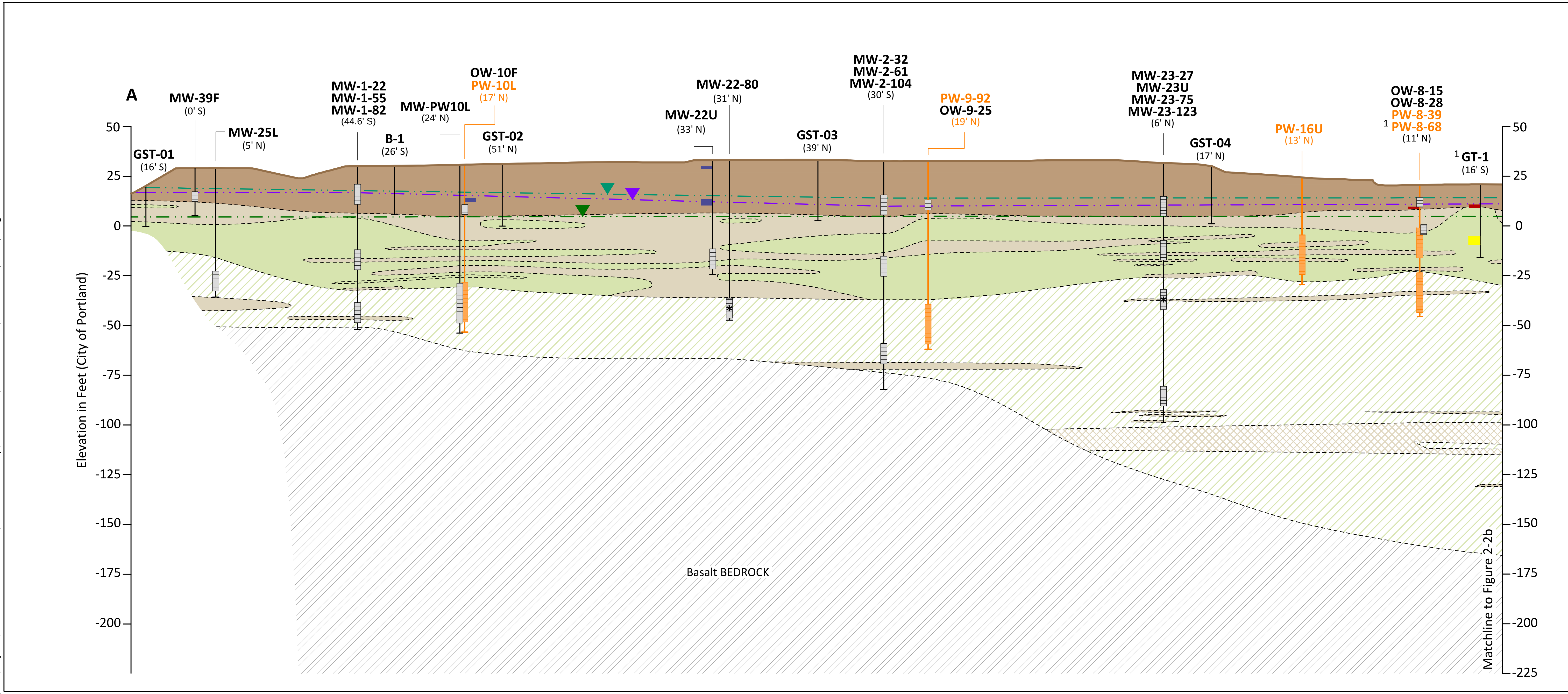
LEGEND:

- MW-2-12 — Existing Monitoring Well, Observation Well, or Piezometer
- PW-9L — Existing Extraction Well (U = Upper Alluvium, L = Lower Alluvium)
- B-43 — Soil Boring
- TG-6 — TarGOST Boring
- DW-11U — DNAPL Well
- SG3 — Staff Gauge
- Property Boundary
- B — Cross Section Location and Designation

0 160
Scale in Feet

ANCHOR QEA

Figure 2-1
Explorations and Cross Section Location Map
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-003 (XSECS).dwg 2-2a

Apr 07, 2015 12:18pm mpratschner

LEGEND:

Fill WBZ - Fill composed of gravel, silt, sand, metal, brick, and concrete debris

Upper Alluvium WBZ - Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers

Lower Alluvium WBZ - Primarily medium grained SAND with generally less than 5% fines.

Aquitard - Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt

Basalt BEDROCK

Potentiometric Surface of Surficial Fill (measured June 3, 2009)

Potentiometric Surface of Surficial Fill (measured August 5, 2009)

Potentiometric Surface of Alluvium (measured August 5, 2009)

Existing Ground Surface

MW-21-16 — Boring ID

(57' E) — Offset Distance in Feet

Existing Extraction Well

Existing Well or Piezometer

— Tar Interval

— Oil or Mixed Oil and Tar Interval

— Sheen Interval

— Well Screen

* — Control Well

0 50

Scale in Feet

NOTE: Geologic contacts are inferred between borings.

[1] Based on visual observations and analytical testing conducted by Hahn and Associates (Remedial Investigation Report, Hahn and Associates, April 2007), the oil and sheen detected in the fill unit does not appear to be MGP-related, but appears to be associated with petroleum products stored in the FAMM storage tanks.

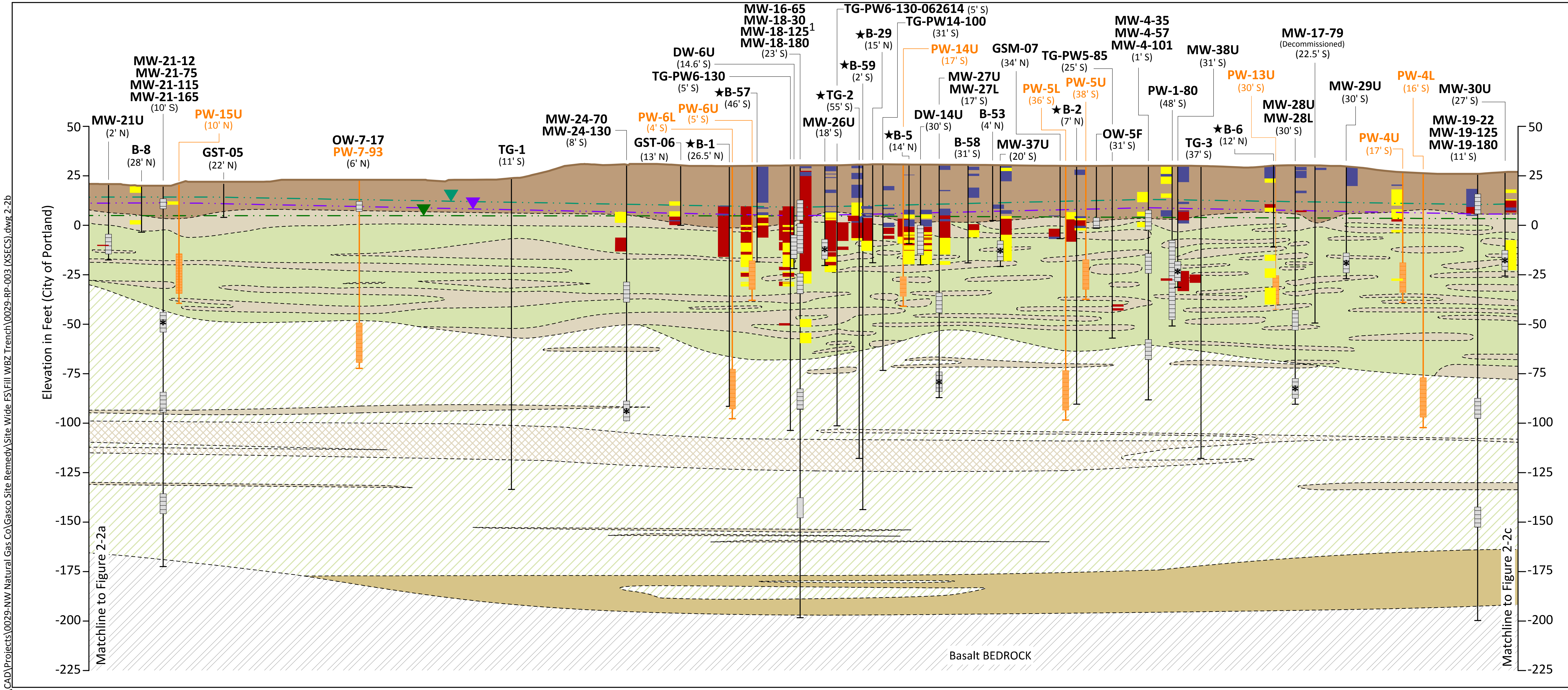
ANCHOR QEA

Figure 2-2a

Geologic Cross Section A-A'

Fill WBZ Trench Design Evaluation Report

NW Natural Gasco/Siltronic Site



LEGEND:

Fill WBZ - Fill composed of gravel, silt, sand, metal, brick, and concrete debris

Upper Alluvium WBZ - Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers

Lower Alluvium WBZ - Primarily medium grained SAND with generally less than 5% fines.

Aquitard - Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt

Basalt BEDROCK

Potentiometric Surface of Surficial Fill (measured June 3, 2009)

Potentiometric Surface of Surficial Fill (measured August 5, 2009)

Potentiometric Surface of Alluvium (measured August 5, 2009)

Existing Ground Surface

MW-21-16 — Boring ID
(57' E) — Offset Distance in Feet

Existing Extraction Well
Existing Well or Piezometer

— Tar Interval
— Oil or Mixed Oil and Tar Interval
— Sheen Interval
— Well Screen
* — Control Well

0 50
Scale in Feet

NOTE: Geologic contacts are inferred between borings.

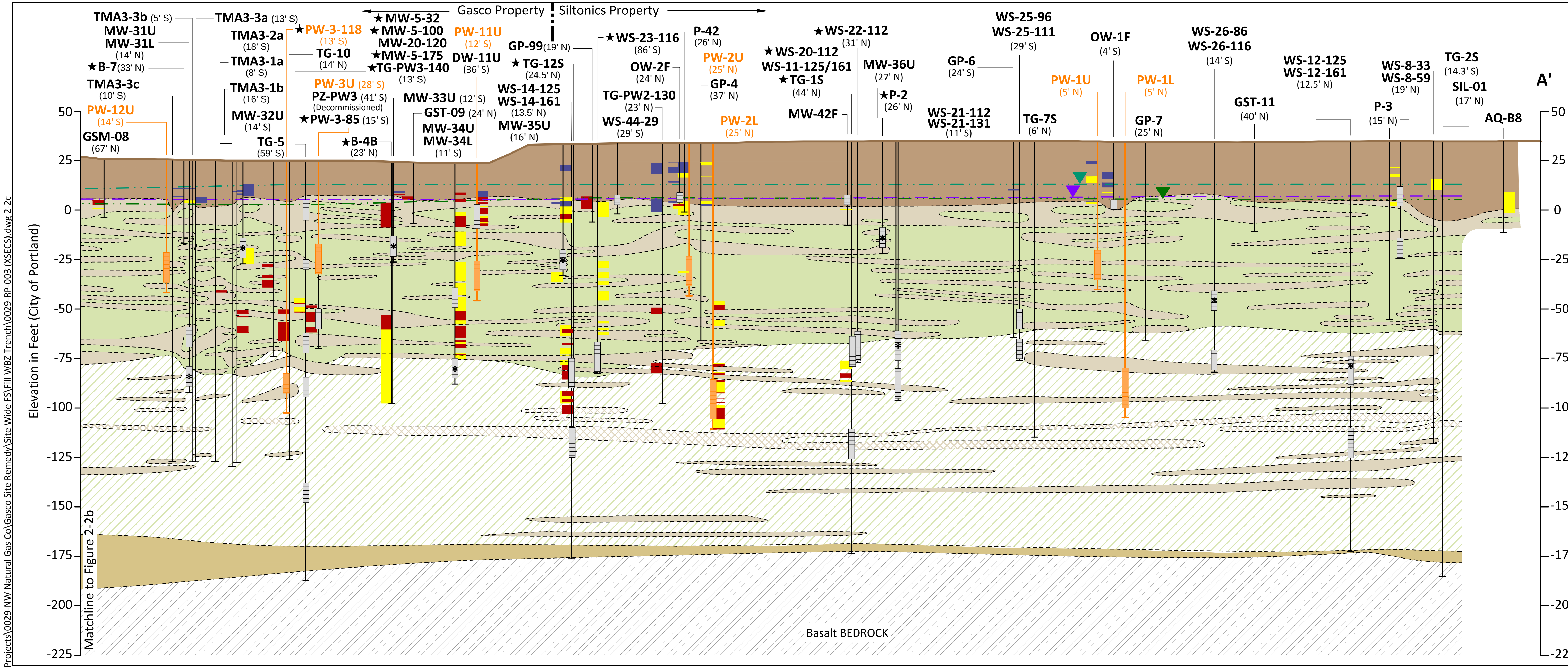
★ Not used for geologic interpretation.

1 Data from MW-18-125 used for geologic interpretation from ground surface to -94 feet elevation. Data from MW-18-180 used for geologic interpretation from -94 to -198 feet elevation.

T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-003 (XSECS).dwg 2-2b

Apr 07, 2015 12:19pm mpratschner

Figure 2-2b
Geologic Cross Section A-A'
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



LEGEND:

Fill WBZ - Fill composed of gravel, silt, sand, metal, brick, and concrete debris

Upper Alluvium WBZ - Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers

Lower Alluvium WBZ - Primarily medium grained SAND with generally less than 5% fines.

Aquitard - Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt

Basalt BEDROCK

Potentiometric Surface of Surficial Fill (measured June 3, 2009)

Potentiometric Surface of Surficial Fill (measured August 5, 2009)

Potentiometric Surface of Alluvium (measured August 5, 2009)

Existing Ground Surface

MW-21-16 — Boring ID

(57' E) — Offset Distance in Feet

Existing Extraction Well

Existing Well or Piezometer

— Tar Interval

— Oil or Mixed Oil and Tar Interval

— Sheen Interval

— Well Screen

* — Control Well

0 50

Scale in Feet

NOTE: Geologic contacts are inferred between borings.

★ Not used for geologic interpretation.

T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-003 (XSECS).dwg 2-2c

Apr 07, 2015 12:20pm mpratschner

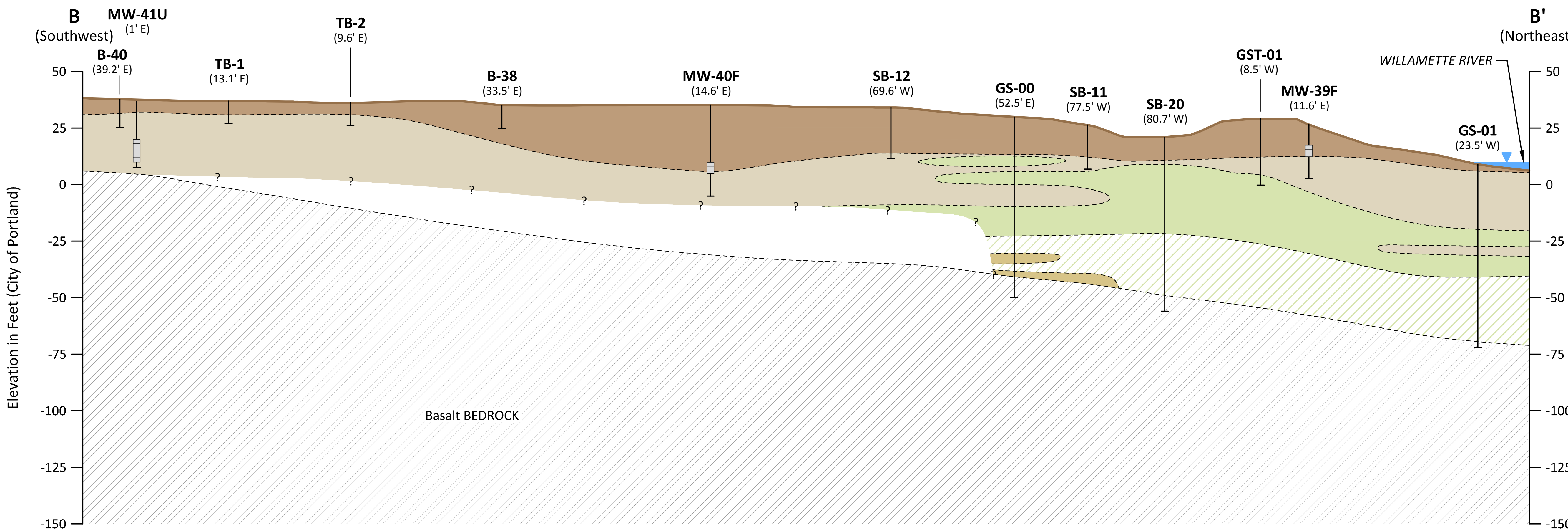
ANCHOR QEA

Figure 2-2c

Geologic Cross Section A-A'

Fill WBZ Trench Design Evaluation Report

NW Natural Gasco/Siltronic Site



LEGEND:

Fill WBZ - Fill composed of gravel, silt, sand, metal, brick, and concrete debris

Upper Alluvium WBZ - Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers

Lower Alluvium WBZ - Primarily medium grained SAND with generally less than 5% fines.

Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers

Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt

Basalt BEDROCK

Existing Ground Surface

Approximate Willamette River Elevation

B-38 — Boring ID
(33.5' E) — Offset Distance in Feet

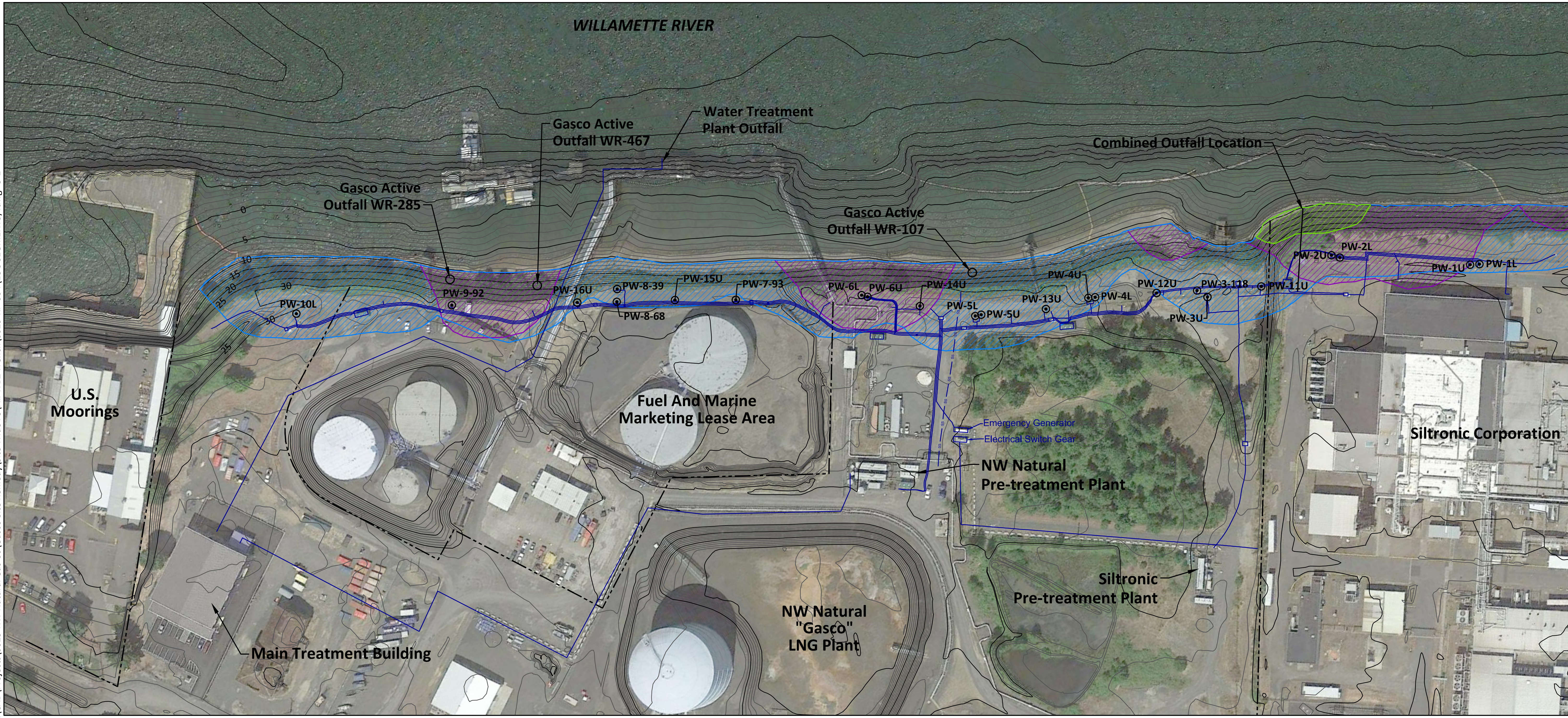
Existing Well or Piezometer

0 50
Scale in Feet

NOTES:
1. Geologic contacts are inferred between borings.
2. Except where boring investigations encountered bedrock, the basalt bedrock surface was interpolated from the geologic unit structure contour map of the top of bedrock surface created for the Groundwater Source Control model.

Figure 2-3
Geologic Cross Section B-B'
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site

ANCHOR QEA



T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-004 (LOC SEGMENTS) .dwg 3-1

Apr 07, 2015 12:26pm mpratschner

SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

LEGEND:

PW-2U ⦿ Existing Extraction Well

Source Control Main Pipeline Route

Major Topographic Surface Contour (5' Interval)

Minor Topographic Surface Contour (1' Interval)

Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)

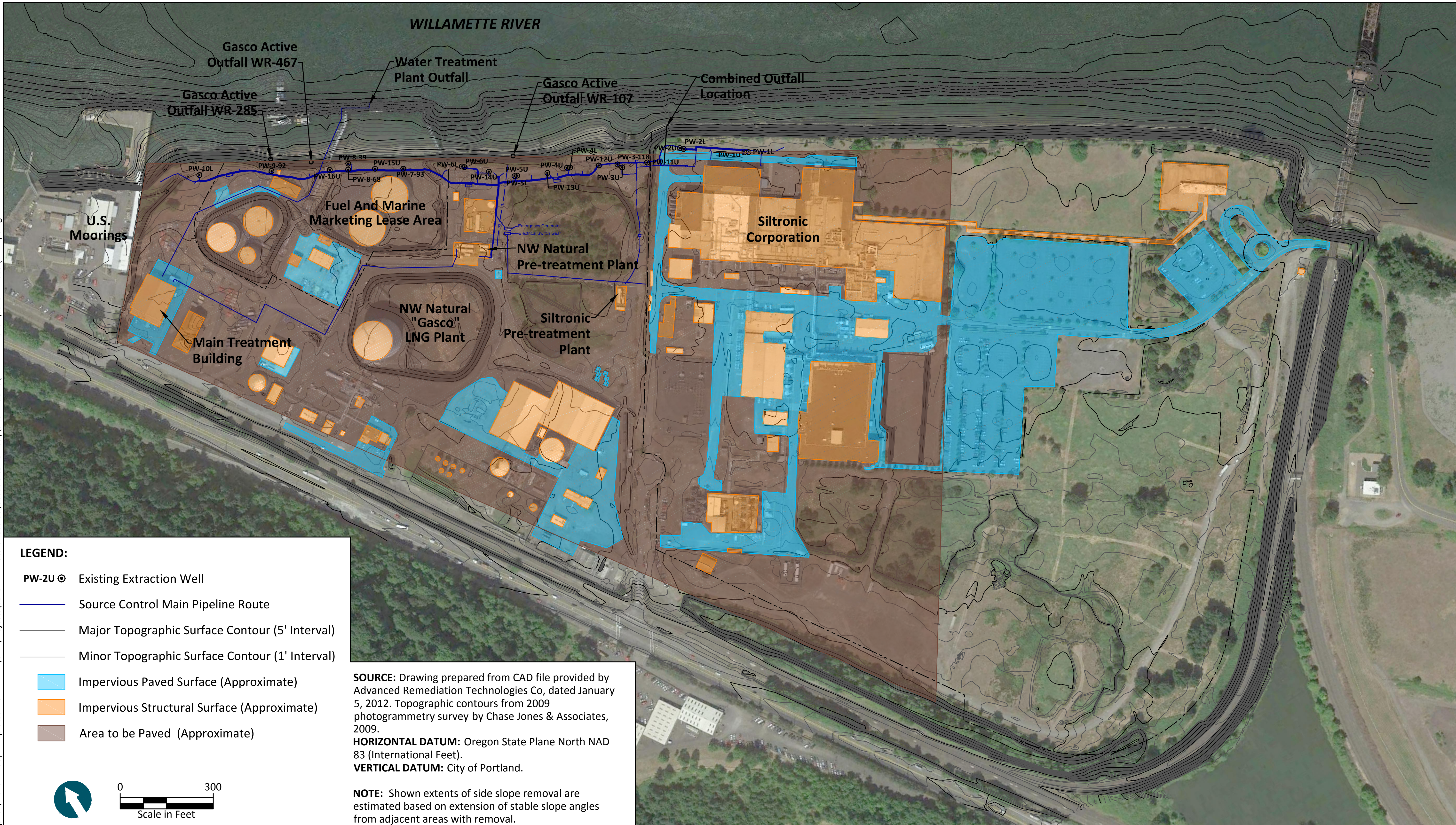
Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)

Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)

0 150
Scale in Feet

ANCHOR QEA

Figure 3-1
Factors Affecting Fill WBZ Source Control Design and Implementation
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

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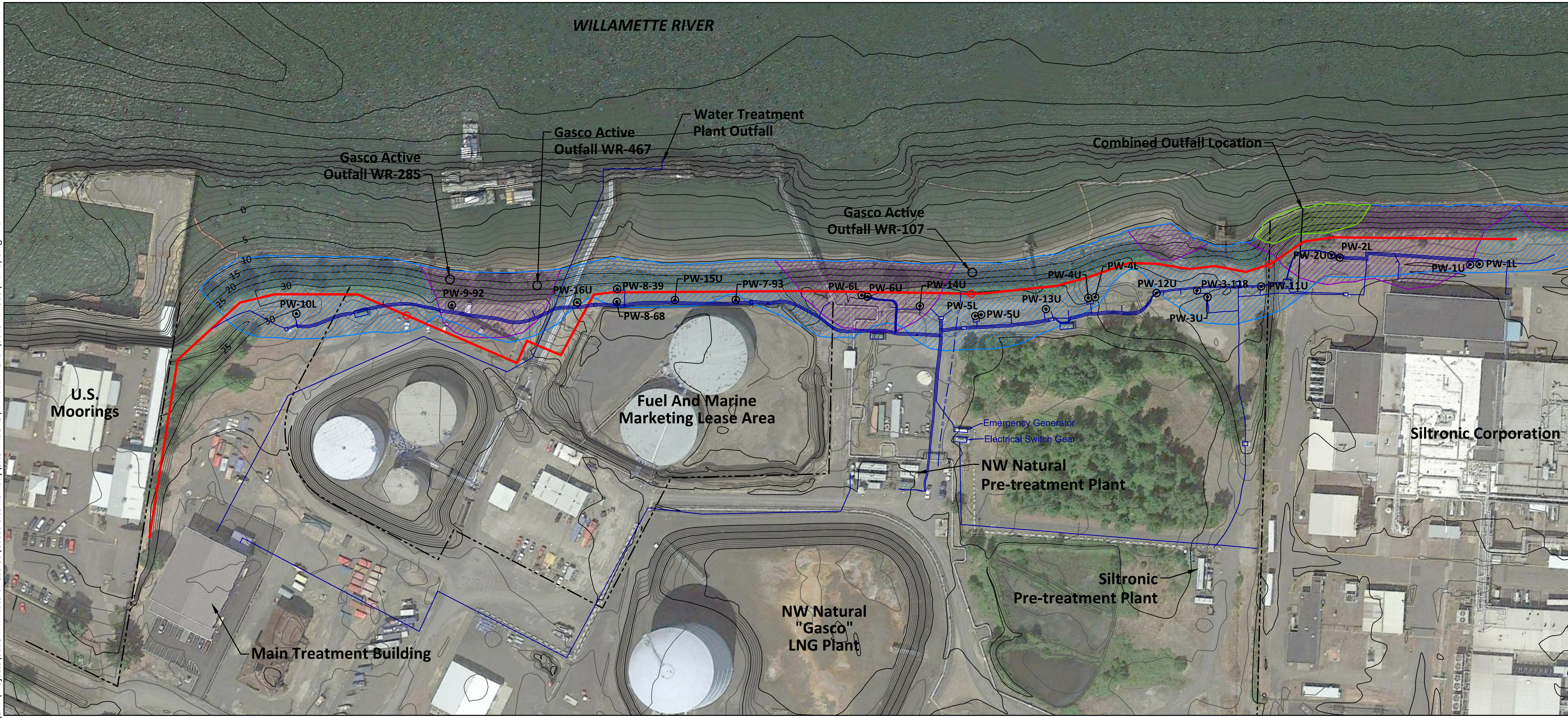
Apr 07, 2015 12:55pm mpratschner

ANCHOR QEA

Figure 4-1
Alternative 1 - Upland Paving and HC&C System
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



T:\CAD\Projects\0029-NW Natural Gas Co\Gasco Site Remedy\Site Wide FS\Fill WBZ Trench\0029-RP-006 (ALT 2).dwg 4-2

Apr 07, 2015 1:12pm mpratschner

SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

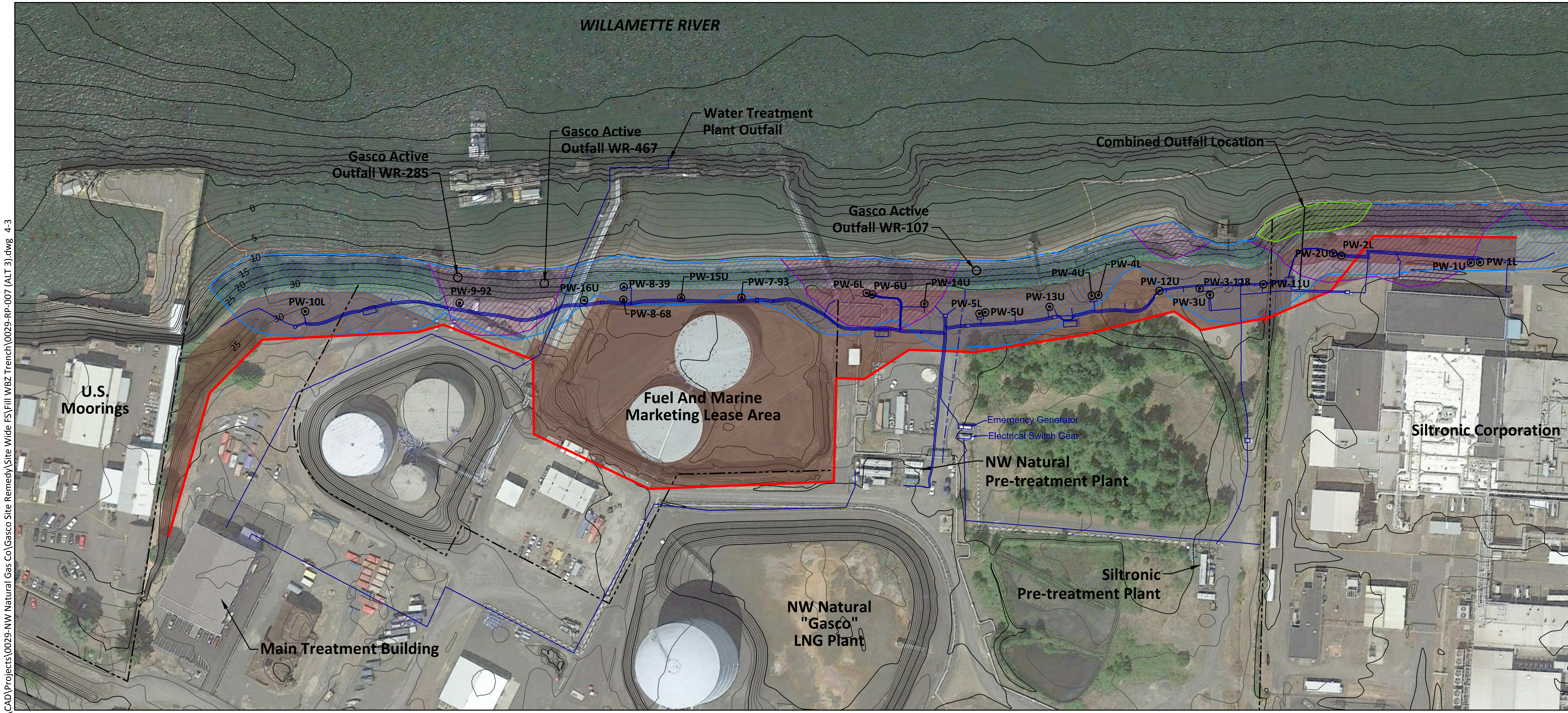
LEGEND:

- PW-2U ⊙ Existing Extraction Well
- Proposed Fill WBZ Interceptor Trench Alignment (Install Immediately)
- Source Control Main Pipeline Route
- Approximate Manhole Location
- Major Topographic Surface Contour (5' Interval)
- Minor Topographic Surface Contour (1' Interval)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)

0 150
Scale in Feet

ANCHOR QEA

Figure 4-2
Alternative 2 - Interceptor Trench Near Slope Crest Built Continuously
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.

HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).

VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

LEGEND:

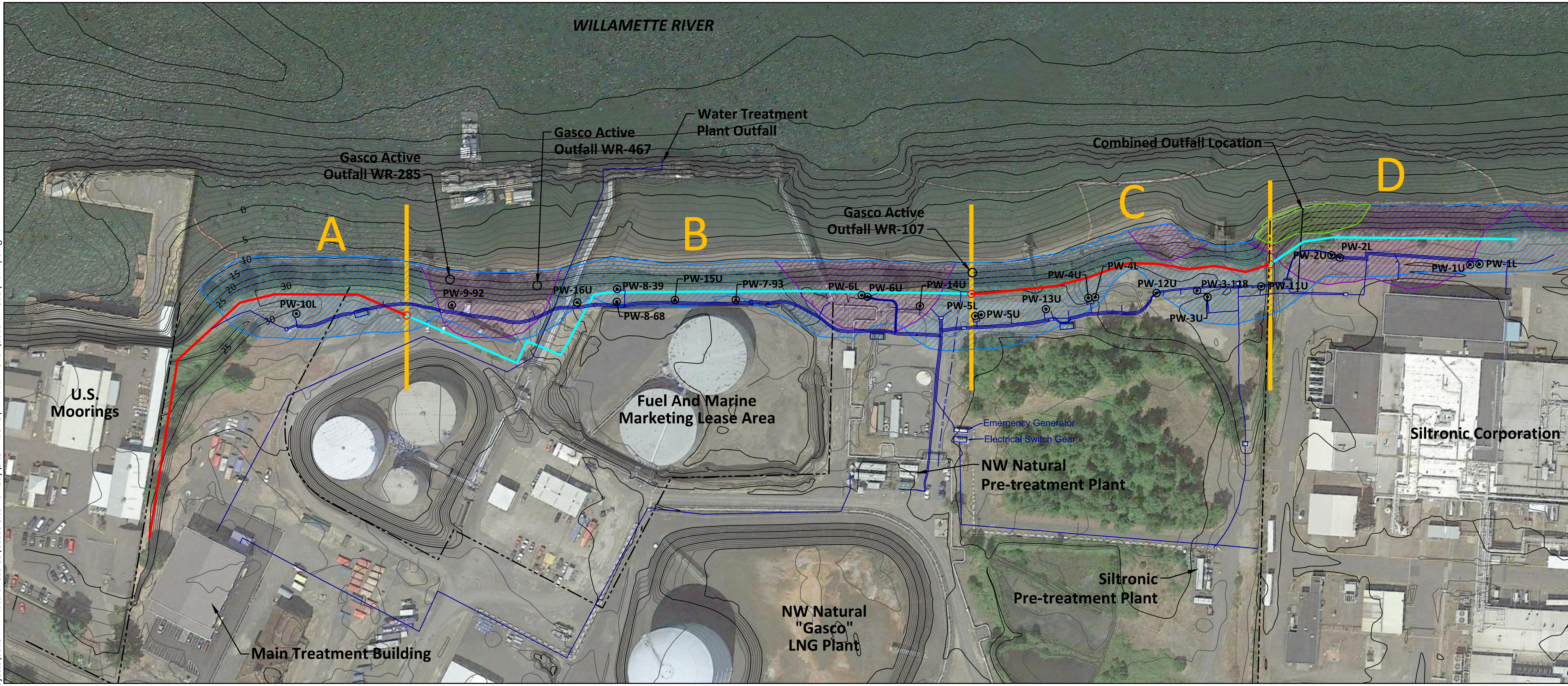
- **PW-2U** Existing Extraction Well
- Proposed Fill WBZ Interceptor Trench Alignment (Install Immediately)
- Source Control Main Pipeline Route
- Approximate Manhole Location
- Major Topographic Surface Contour (5' Interval)
- Minor Topographic Surface Contour (1' Interval)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)
- Area to be Paved (Approximate)

0 150
Scale in Feet

ANCHOR QEA

Figure 4-3

Alternative 3 - Interceptor Trench Back From Slope Crest Built Continuously
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

LEGEND:

- PW-2U — Existing Extraction Well
- Proposed Fill WBZ Interceptor Trench Alignment (Install Immediately)
- Proposed Fill WBZ Interceptor Trench Alignment (Install at a Later Time)
- Approximate Manhole Location
- Source Control Main Pipeline Route
- Major Topographic Surface Contour (5' Interval)
- Minor Topographic Surface Contour (1' Interval)
- A | B — Segment Identification
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)

0 150
Scale in Feet

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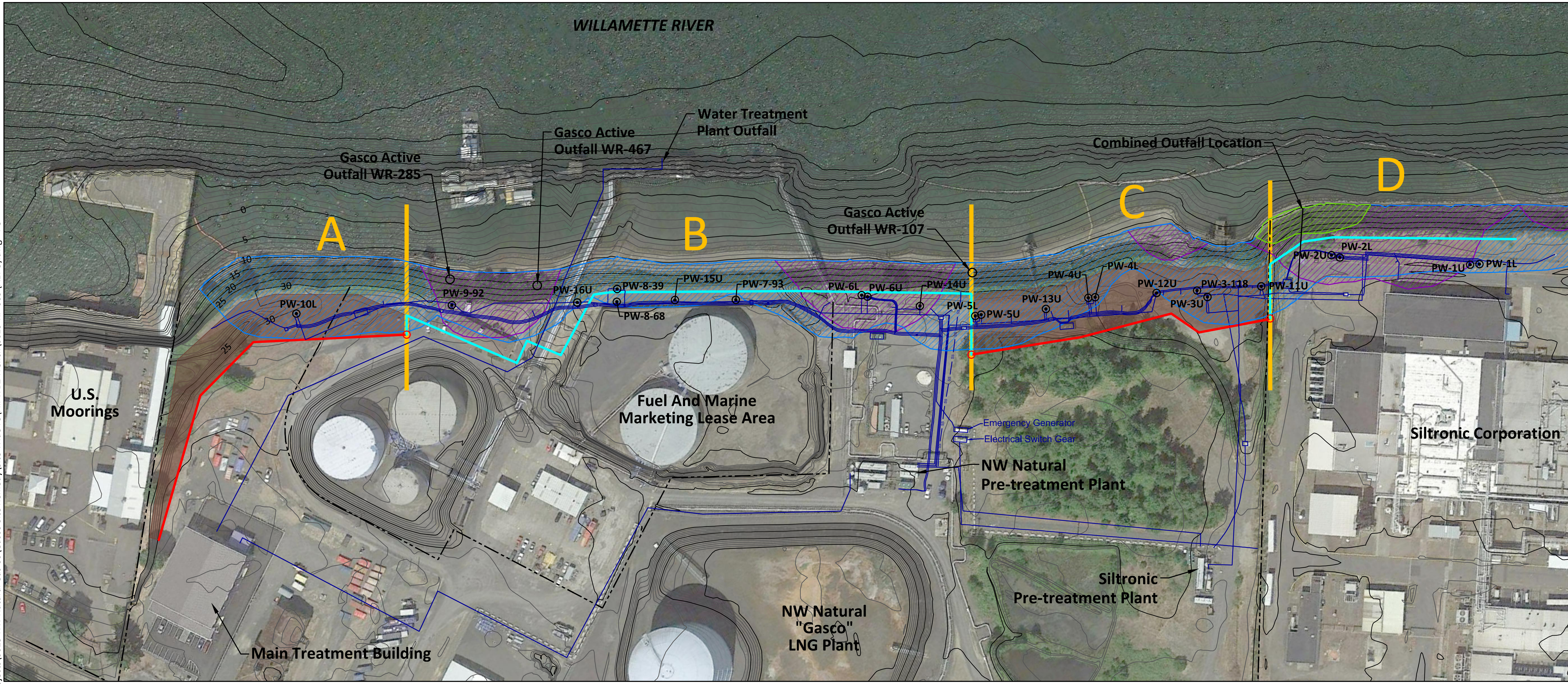
Apr 07, 2015 1:32pm mpratschner

ANCHOR QEA

Figure 4-4
Alternative 4 - Interceptor Trench Near Slope Crest Built in Segments
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

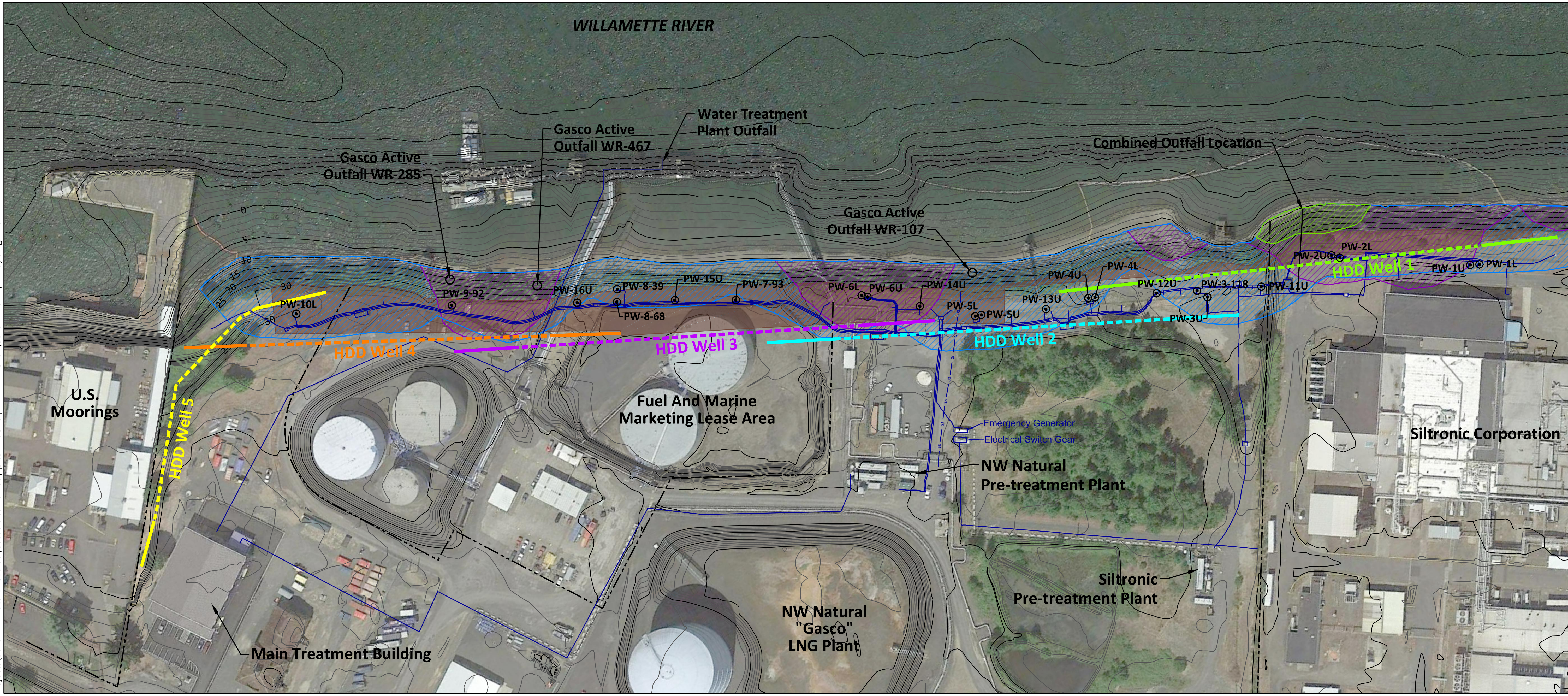
LEGEND:

- PW-2U ⊙ Existing Extraction Well
- Proposed Fill WBZ Interceptor Trench Alignment (Install Immediately)
- Proposed Fill WBZ Interceptor Trench Alignment (Install at a Later Time)
- Approximate Manhole Location
- Source Control Main Pipeline Route
- Major Topographic Surface Contour (5' Interval)
- Minor Topographic Surface Contour (1' Interval)
- A|B Segment Identification
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)
- Area to be Paved (Approximate)

0 150
Scale in Feet

ANCHOR QEA

Figure 4-5
Alternative 5 - Interceptor Trench at Different Offsets Built in Segments
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site



SOURCE: Drawing prepared from CAD file provided by Advanced Remediation Technologies Co, dated January 5, 2012. Topographic contours from 2009 photogrammetry survey by Chase Jones & Associates, 2009.
HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

NOTE: Shown extents of side slope removal are estimated based on extension of stable slope angles from adjacent areas with removal.

LEGEND:

- PW-2U ⊙ Existing Extraction Well
- Source Control Main Pipeline Route
- Major Topographic Surface Contour (5' Interval)
- Minor Topographic Surface Contour (1' Interval)
- Proposed HDD Inclined Access Drain Alignment
- Proposed HDD Horizontal Drain Alignment
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 3 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 4 (Anchor QEA 2012)
- Riverbank Cutback Associated with the Draft EE/CA Remedial Footprint for Alternative 5 (Anchor QEA 2012)
- Area to be Paved (Approximate)

0 150
Scale in Feet

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Apr 07, 2015 1:57pm mpratschner

ANCHOR QEA

Figure 4-6
Alternative 6 - Horizontal-Drilled Interceptor Drain
Fill WBZ Trench Design Evaluation Report
NW Natural Gasco/Siltronic Site

APPENDIX A
DATA REPORT

DATA GAPS REPORT
NW NATURAL GASCO SITE

Prepared for

NW Natural

Prepared by

Anchor QEA, LLC

6650 SW Redwood Lane, Suite 333

Portland, Oregon 97224

April 8, 2015

TABLE OF CONTENTS

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LIST OF ACRONYMS AND ABBREVIATIONS

Anchor QEA	Anchor QEA, LLC
ASTM	ASTM International
bgs	below ground surface
COP	City of Portland datum
DEQ	Oregon Department of Environmental Quality
HC&C	hydraulic control and containment
MW	monitoring well
Siltronic	Siltronic Corporation
Site	Gasco Site
SPT	standard penetration test
USEPA	U.S. Environmental Protection Agency
WBZ	Water-Bearing Zone

1 INTRODUCTION

This data report summarizes and presents the findings of data gaps investigations performed in November 2014 at the Gasco Site (Site) in Portland, Oregon (Figures 1 and 2). This data gaps investigation was performed as directed by the Oregon Department of Environmental Quality (DEQ) to address the data gaps identified in the *Fill WBZ Trench Investigation Work Plan* (Work Plan; Anchor QEA 2013).

2 FIELD SAMPLING SUMMARY

Field sampling performed at the Site as part of the data gaps investigation included five upland soil borings, with co-located monitoring wells installed at four of the five locations. Field activities were performed by or under the direction of an Anchor QEA registered geologist. Cascade Drilling, Inc., was contracted to advance the soil borings and install the monitoring wells. Work was performed from November 17 to November 25, 2014. Soil samples were transported to Northwest Testing, Inc., and validated laboratory results were received on January 8, 2015.

2.1 Soil Borings and Sampling

Soil borings were advanced using a sonic drill rig. Explorations were advanced with a 6-inch-diameter casing and 4-inch core barrels. Disturbed geotechnical samples (split spoon samples) were obtained at intervals and locations described in the Work Plan (Anchor QEA 2013). Consistent with the Work Plan, undisturbed samples (Shelby tube samples) were collected in the underlying silt unit (alluvium) with the intent of sampling the more permeable sandy layers at locations MW-40F and MW-42F. Split spoon samples were obtained at 2.5-foot intervals in the upper 10 feet, and every 5 feet thereafter. Standard penetration test (SPT-N) blow count data was recorded at each interval were disturbed samples were collected.

2.2 Monitoring Wells

Consistent with the Work Plan and using methods described in the *Sampling and Analysis Plan and Quality Assurance Project Plan* (Anchor QEA 2014), monitoring wells were installed at four of the five exploration locations: MW-39F, MW-40F, MW-41U, and MW-42F.

2.3 Work Plan Deviations

At boring location MW-41U, it was determined that there was no Fill Water-Bearing Zone (WBZ) because the fill was approximately 6 feet thick and dry. Instead, the boring was advanced to 30 feet below ground surface (bgs), and a monitoring well was installed in the Upper Alluvium from 17.6 to 27.6 feet bgs.

3 INVESTIGATION RESULTS

The findings of the data gaps investigation are presented in this section. Soil boring logs are included as Attachment A.

The *Trench Design Alternatives Evaluation Report* contains detailed descriptions of fill characteristics adjacent to U.S. Moorings property and near the top of the riverbank on NW Natural and Siltronic Corporation (Siltronic) property, using subsurface data from this data gaps investigation and combining that information with other sources.

3.1 Subsurface Conditions

Characterization of subsurface conditions was performed during soil borings through observations of a continuous core and data collected from regular intervals from the ground surface to the final boring depth. Two principal soil units were identified during the investigation: fill and alluvium. All soil borings were terminated in the alluvium.

3.1.1 *Fill*

The upper soil unit encountered at each exploration location consisted of fill. In general, the surficial layer of the fill consisted of variable amounts of gravel, silt, and sand. This surficial gravelly layer was generally 0.5 to 2.5 feet thick. Based on SPT-N blow counts, this surficial layer is loose to medium dense with occasional hard layers.

Beneath the upper gravelly layer, the fill unit generally consisted of a soft, loose or medium dense, dry to wet, dark brown to yellow-brown or gray, silty fine sand or sandy silt with non-plastic to low plasticity fines. Occasional gravel and rock fragments and varying amounts of organic matter were encountered in the fill. The fill unit varied in thickness from 2 to 35 feet, with an average thickness of 20 feet.

Anthropomorphic debris (brick, concrete, and wood) were commonly encountered in the fill unit on NW Natural property (MW-39F, MW-40F, and MW-41U) and were generally not encountered on Siltronic property (MW-42F and AQ-B8).

3.1.2 *Alluvium*

Beneath the fill, alluvium soils were encountered at all exploration locations. All explorations were terminated in the alluvium soil unit (to a maximum depth of 45 feet bgs). In general, alluvium soils consisted of wet, soft or loose, gray to dark gray, fine to medium sand, silty sand, or low plasticity silt to sandy silt.

3.2 Groundwater

To address data gaps identified in the Work Plan (Anchor QEA 2013), four Fill WBZ monitoring wells and one Fill WBZ boring were installed at the Site. Three monitoring wells (MW-39F, MW-40F, and MW-41U) were installed along the Gasco U.S. Moorings property line. One monitoring well (MW-42F) and one soil boring (AQ-B8) were completed along the waterfront on the Siltronic property. These wells, in addition to existing Fill WBZ observation wells (OW-1F, OW-2F, OW-5F, OW-7-17, OW-8-15, OW-9-25, and OW-10F) and Siltronic fill monitoring wells (WS-44-29, WS-45-23, and WS-46-33), had a round of water levels completed on January 25, 2015. The depth of water measurements and elevations converted to City of Portland datum (COP) are in Table 1.

Groundwater levels in shoreline area Fill WBZ monitoring wells behave differently depending on the seasonal river stage at the time of measurement. For example, a Fill WBZ monitoring well may not respond to diurnal tidal river changes during a low river stage, but it may respond to tidal river changes at a higher river stage. This stage-dependent response was observed during the Segment 2 pump tests conducted in May and November 2010. In May, when river levels were seasonally high, hydrographs from Fill WBZ observation wells OW-7-17, OW-8-15, and OW-9-25 clearly showed river tidal fluctuations. During additional testing in November, when river levels were seasonally low, no tidal fluctuations were observed in these wells. In addition, water level data obtained during Phase 1 hydraulic control and containment (HC&C) system testing were consistent with these observations. Groundwater elevation hydrographs for the shoreline area Fill WBZ monitoring wells were prepared for all periods during Phase 1 Testing (October 2013 through December 2014), as shown in the Figure 3 series.

For better resolution of detail, two time periods were selected, showing approximate 2-week periods of high and low river levels. The Figure 4 series shows a period of high river levels (May 15 through May 31, 2014), and the Figure 5 series shows a period of low river levels (September 17 through September 28, 2014). When the river level was high (above 11 feet COP) in May 2014, tidal influence on groundwater elevations is evident. However, in September 2014, when the river level was low (below 8 feet COP), daily tidal influence on groundwater levels were not evident or very low in many of the fill wells. Wells showing tidal response are typically the 5-foot deep piezometers installed at the shoreline and in the river.

4 GEOTECHNICAL LABORATORY TESTING

Soil samples were collected using methods consistent with the Work Plan (Anchor QEA 2013). Soil samples were sent to Northwest Testing, Inc., for laboratory testing. A discussion of the findings for the geotechnical laboratory testing performed on soil samples is presented in this section. The laboratory report is included as Attachment B. Table 2 presents a summary of laboratory data.

A brief summary of laboratory results for fill and alluvium is presented as follows:

- **Moisture Content** (ASTM D2216)—Forty-eight samples were tested. In general, moisture content increased with increasing silt content and decreased with increasing SPT-N blow counts.
  - **Fill:** Moisture content ranged from ranged from 6 to 48 percent, with an average of 16 percent.
  - **Alluvium:** Moisture content ranged from 11 to 44 percent, with an average of 34 percent.
- **Atterberg Limits** (ASTM D4318)—Due to the generally non-plastic nature of fine-grained soils sampled, only five samples were tested: three in the alluvium and two in the fill. Laboratory tests indicate soils are low plasticity silt or clay.
- **Particle Size Analysis** (ASTM D422/421)—Thirteen samples were tested for particle size distribution; five of these samples were tested for clay fraction.
  - **Fill:** Fill soils were generally sand or silt with variable amounts of gravel (maximum 26 percent) and clay (maximum 14 percent).
  - **Alluvium:** Alluvium soils were generally silty sand or sandy silt with little to no gravel (maximum 6 percent) and significant clay content (maximum 26 percent).
- **Vertical Permeability Testing** (ASTM D5084 Method C)—Vertical permeability tests were performed on samples obtained with Shelby tubes with the intent of testing more permeable layers of the upper alluvium unit. The average permeability of each sample (based on five sub-tests) is as follows:
  - MW-40F: 26.5 to 29 feet
    - 6.56×10^{-6} cm/sec
  - MW-42F: 31.5 to 33.5 feet
    - 5.31×10^{-7} cm/sec

5 REFERENCES

Anchor QEA (Anchor QEA, LLC), 2012. *Revised Groundwater Source Control Construction Design Report*. NW Natural Gasco Site. In Association with Sevenson Environmental Services, Inc. and Advanced Remediation Technologies, Inc. Prepared for NW Natural. January 2012.

Anchor QEA, 2013. *Fill WBZ Trench Investigation Work Plan*. Revised. Gasco/Siltronic. Prepared for NW Natural. November 2013.

Anchor QEA, 2014. *Sampling and Analysis Plan and Quality Assurance Project Plan*. NW Natural Gasco Site. Prepared for Oregon Department of Environmental Quality. September 2014.

DEQ (Oregon Department of Environmental Quality), 2014. Letter from Dana Bayuk to NW Natural. Regarding: Revised Fill Water-Bearing Zone Trench Investigation Work Plan – Shoreline Segments 1 and 2, NW Natural Property and the Northern Portion of the Siltronic Corporation Property. April 28, 2014.

TABLES

Table 1
Monitoring Well Data

Well Number/ Soil Boring ID	Installed Transducer	Water-Bearing Zone	Date Installed/ Explored	Date Decommissioned	Installation Method	Monument Type	Screen Type	Slot Size (inches)	Sand Pack (Colorado)	Well Diameter (inches)	Ground Surface (feet COP)	Top of Casing		Pump Inlet		Top Screen		Base Screen		Well Depth[1]		Exploration Depth		Fill Unit/ Alluvium Contact		Static Water Level[3]	
												feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP	feet bgs	feet COP
MW-39F	N	Surficial Fill	17-Nov-14	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	31.1	-3.16	34.25	NA	NA	11.8	19.3	16.9	14.2	17.3	13.8	26.5	4.6	16.6	14.5	16.2	14.9
MW-40F	N	Surficial Fill	18-Nov-14	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	36.0	-3.27	39.25	NA	NA	21.6	14.4	26.7	9.3	27.1	8.9	36.5	-0.5	22.1	13.9	16.4	19.6
MW-41U	N	Alluvial	16-Jan-15	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	37.6	-3.14	40.69	NA	NA	17.6	20.0	27.6	10.0	28.0	9.6	30.0	7.6	2.0	35.6	17.6	20.0
MW-42F	N	Surficial Fill	21-Nov-14	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	33.5	-3.36	36.84	NA	NA	26.0	7.5	31.0	2.5	31.4	2.1	41.5	-8.0	31.1	2.4	23.2	10.3
OW-1F	Y	Surficial Fill	23-Mar-12	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	35.3	-2.28	37.60	NA	NA	30.0	5.3	35.0	0.3	35.3	0.0	40.0	-4.7	35.0	0.3	24.7	10.6
OW-2F	Y	Surficial Fill	22-Mar-12	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	34.5	-2.40	36.86	NA	NA	25.6	8.9	30.6	3.9	30.9	3.6	35.0	-0.5	30.6	3.9	21.3	13.2
OW-5F	Y	Surficial Fill	29-Nov-12	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	32.2	-2.50	34.70	NA	NA	28.5	3.7	33.5	-1.3	33.8	-1.6	35.0	-2.8	33.5	-1.3	22.2	10.0
OW-7-17	Y	Surficial Fill	23-Feb-10	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	24.2	-2.22	26.42	NA	NA	12.5	11.7	17.5	6.7	17.7	6.5	17.7	6.5	17.5	6.7	11.9	12.3
OW-8-15	Y	Surficial Fill	12-Feb-10	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	24.6	-1.75	26.31	NA	NA	10.1	14.5	15.1	9.5	15.3	9.3	16.5	8.1	15.8	8.8	12.0	12.6
OW-9-25	Y	Surficial Fill	8-Mar-10	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	33.1	-2.18	35.29	NA	NA	20.0	13.1	25.0	8.1	25.3	7.8	25.3	7.8	26.3	6.8	21.5	11.6
OW-10F	Y	Surficial Fill	20-Sep-12	NA	Sonic	Above-grade	Slotted PVC	0.020	10-20	2	30.8	-2.95	33.75	NA	NA	20.7	10.1	25.7	5.1	26.0	4.8	30.0	0.8	25.4	5.4	18.9	11.9
WS-44-29	Y	Surficial Fill	16-Aug-13	NA	Sonic	Flush-mount	Slotted PVC	0.010	10-20	2	NA	NA	33.75	NA	NA	24.4	NA	29.4	NA	29.7	NA	35.0	NA	28.9	NA	NA	10.2
WS-45-23	Y	Surficial Fill	22-Aug-13	NA	Sonic	Flush-mount	Slotted PVC	0.010	10-20	2	NA	NA	33.71	NA	NA	17.7	NA	22.7	NA	23.0	NA	40.0	NA	22.7	NA	NA	15.0
WS-46-33	Y	Surficial Fill	15-Aug-13	NA	Sonic	Flush-mount	Slotted PVC	0.010	10-20	2	NA	NA	35.13	NA	NA	28.35	NA	33.35	NA	33.7	NA	35.0	NA	33.6	NA	NA	15.3

Notes:
1 = Actual completion depths may differ depending on actual lithology encountered during drilling.
2 = 2-inch PVC monitoring well installed inside a pre-existing 6-inch well.
3 = Static water level measured on January 26, 2015.
bgs = below ground surface
btc = below top of casing
COP = City of Portland datum
MW = monitoring well and co-located soil boring
NA = not applicable
PVC = polyvinyl chloride

Table 2
Summary of Laboratory and In Situ Data

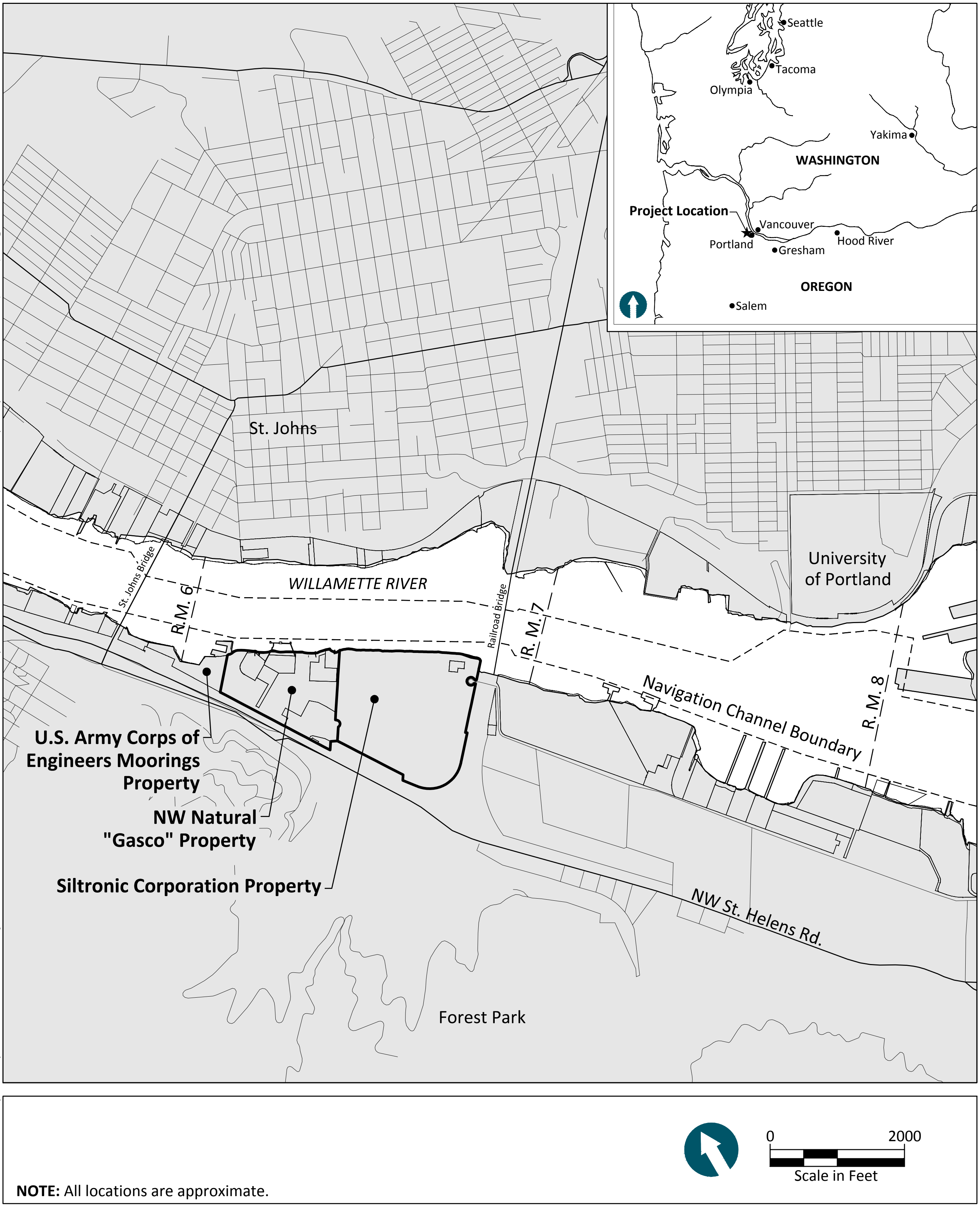
Boring/ Monitoring Well	Depth Upper	Depth Lower	Uncorrected Standard Penetration Resistance ASTM D1586	Moisture Content ASTM D2216	Dry Density ASTM D2937	Atterberg Limits ASTM D4318			Flexible Wall Permeability ASTM D5084 - Method C	Grain Size Distribution ASTM D422/D421				
						Liquid Limit	Plastic Limit	Plasticity Index	Average[1]	Gravel	Sand	Fines (Silt and Clay)	Silt	Clay
	Feet	Feet	Blows/foot	%	pcf	%			cm/sec	%	%	%	%	%
AQ-B8	0	1.5	18	11.2										
AQ-B8	2.5	4	26	10.1						1	92.2	6.8		
AQ-B8	5	6.5	11	9.3										
AQ-B8	7.5	9	22	9.4										
AQ-B8	10	11.5	30	12.4										
AQ-B8	15	16.5	16	12.4										
AQ-B8	20	21.5	14	10.1										
AQ-B8	25	26.5	7	8.8						3	89.6	7.4		
AQ-B8	30	31.5	5	29.8										
AQ-B8	35	36.5	2	39										
AQ-B8	40	41.5	5	37										
MW-39F	0	1.5	6	17.5										
MW-39F	2.5	4	42	10.5										
MW-39F	5	6.5	7	17.1						25	30	45	31	14
MW-39F	7.5	9	13	16.1										
MW-39F	10	11.5	11	18.8										
MW-39F	15	16.5	7	47.7										
MW-39F	20	21.5	4	38.8		38	32	6		6	39	55	44.5	10.5
MW-39F	25	26.5	4											
MW-40F	0	1.5	7	11.8										
MW-40F	2.5	4	8	16.5						26	58.6	15.4		
MW-40F	5	6.5	5	17.8		33	20	13						
MW-40F	7.5	9	3											
MW-40F	10	11.5	6	25.4						12	53.3	34.7		
MW-40F	15	16.5	16	18.7										
MW-40F	20	21.5	20	22.9										
MW-40F	25	26.5	7	44.3						0	67.2	32.8		
MW-40F	26.5	29	N/A	52.3*	69.7**				6.56×10^{-6}					
MW-40F	30	31.5	5	39.6										
MW-40F	35	36.5	6											
MW-41U	0	1.5	5	19.9										
MW-41U	2.5	4	6	11.6						5	83	12	9	3
MW-41U	5	6.5	2	27.4										
MW-41U	7.5	9	9	29.2										
MW-41U	10	11.5	6	33.7						0	10	90	64	26
MW-41U	15	16.5	2	35.7										
MW-41U	20	21.5	4	37.1										
MW-41U	25	26.5	N/A											
MW-42F	0	1.5	41	7.8						20	65.1	14.9		
MW-42F	2.5	4	23	5.8										
MW-42F	5	6.5	22	6.1										

Table 2
Summary of Laboratory and In Situ Data

Boring/ Monitoring Well	Depth Upper	Depth Lower	Uncorrected Standard Penetration Resistance ASTM D1586	Moisture Content ASTM D2216	Dry Density ASTM D2937	Atterberg Limits ASTM D4318			Flexible Wall Permeability ASTM D5084 - Method C	Grain Size Distribution ASTM D422/D421				
						Liquid Limit	Plastic Limit	Plasticity Index	Average[1]	Gravel	Sand	Fines (Silt and Clay)	Silt	Clay
	Feet	Feet	Blows/foot	%	pcf	%			cm/sec	%	%	%	%	%
MW-42F	7.5	9	25	9.8						4	85.3	10.7		
MW-42F	10	11.5	12	10.1										
MW-42F	15	16.5	18	9.6										
MW-42F	20	21.5	43	10.9										
MW-42F	25	26.5	25	12.2						8	66	26	19	7
MW-42F	30	31.5	10	39.6	100.3	40	30	10		3	39.6	57.4		
MW-42F	31.5	33.5	N/A	37.9*	80.5**				5.31×10^{-7}					
MW-42F	35	36.5	3	33.5										
MW-42F	40	41.5	10			36	30	6						

Notes:
1 = The average permeability is evaluated using five permeability tests.
* = Moisture content estimated using ASTM D5084 - Method C.
** = Dry density estimated using ASTM D5084 - Method C.
ASTM = ASTM International
cm/sec = centimeter per second
N/A = not applicable
pcf = pounds per cubic foot

FIGURES



NOTE: All locations are approximate.

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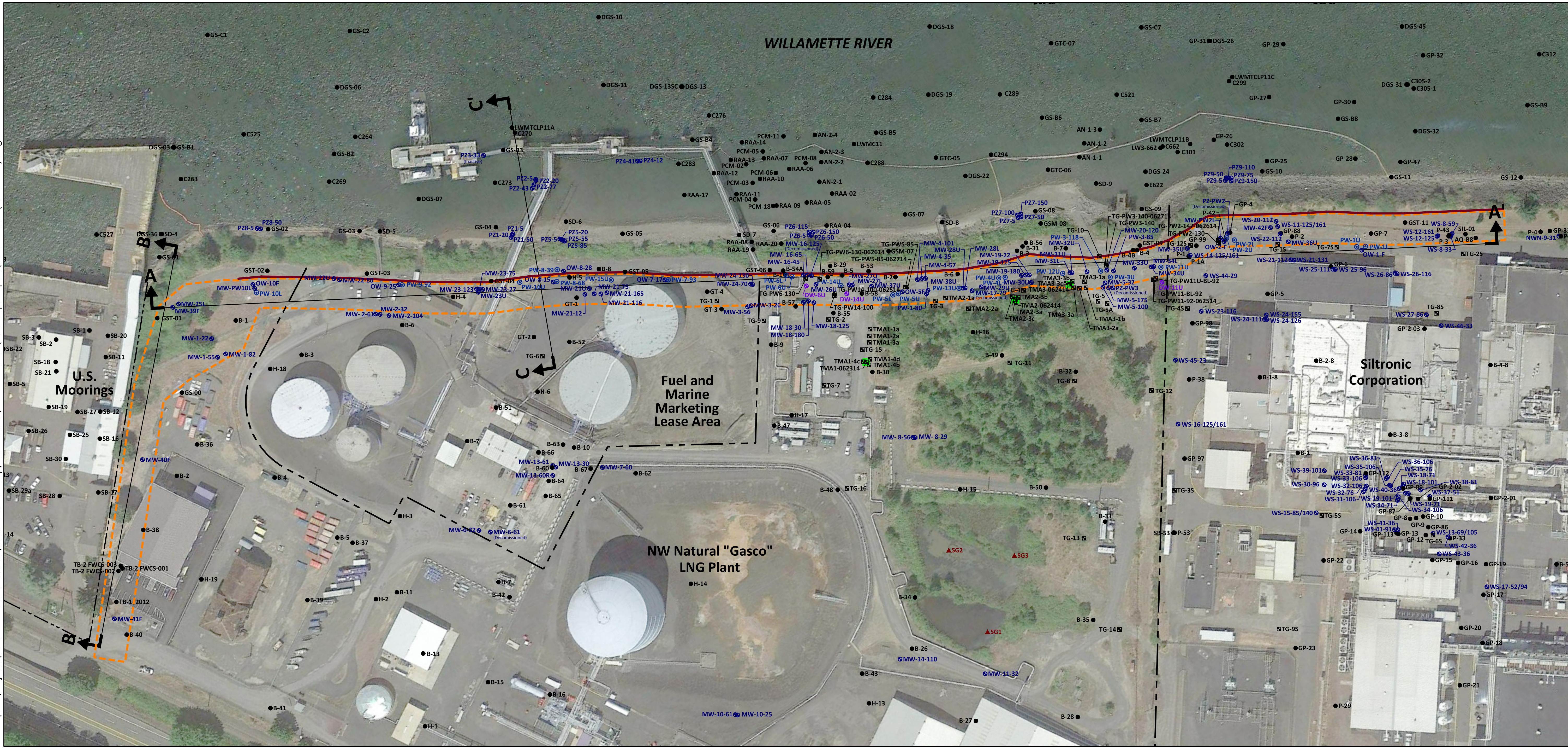
Figure 1
Vicinity Map
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA



LEGEND:

- MW-2-12 Existing Monitoring Well, Observation Well, or Piezometer
- PW-9L Existing Extraction Well (U = Upper Alluvium, L = Lower Alluvium)
- B-43 Soil Boring
- TG-6 TarGOST Boring
- DW-11U DNAPL Well
- SG3 Staff Gauge
- 10-foot by 10-foot TarGOST Monitoring Area
- NW Natural Fill WBZ Trench Alignment
- Area Identified by DEQ as Alternative Trench Alignment
- Property Boundary
- B Cross Section Location and Designation

0 160
Scale in Feet

HORIZONTAL DATUM: Oregon State Plane North NAD 83 (International Feet).
VERTICAL DATUM: City of Portland.

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Feb 25, 2015 1:43pm hhayward

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Figure 2
Monitoring Well and Cross Section Location Map
Data Gaps Report
Gasco/Siltronic

Fill

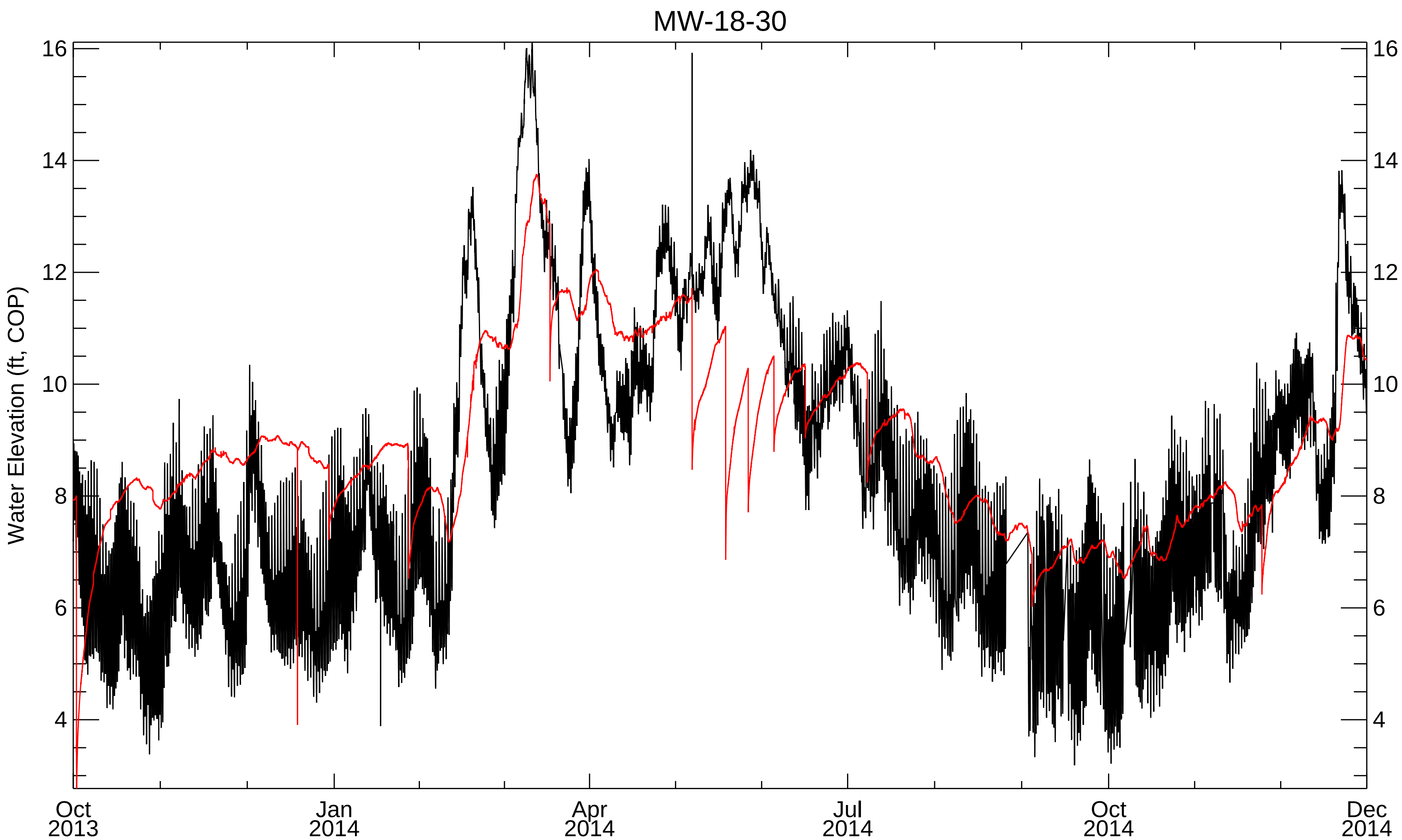

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Figure 3.1
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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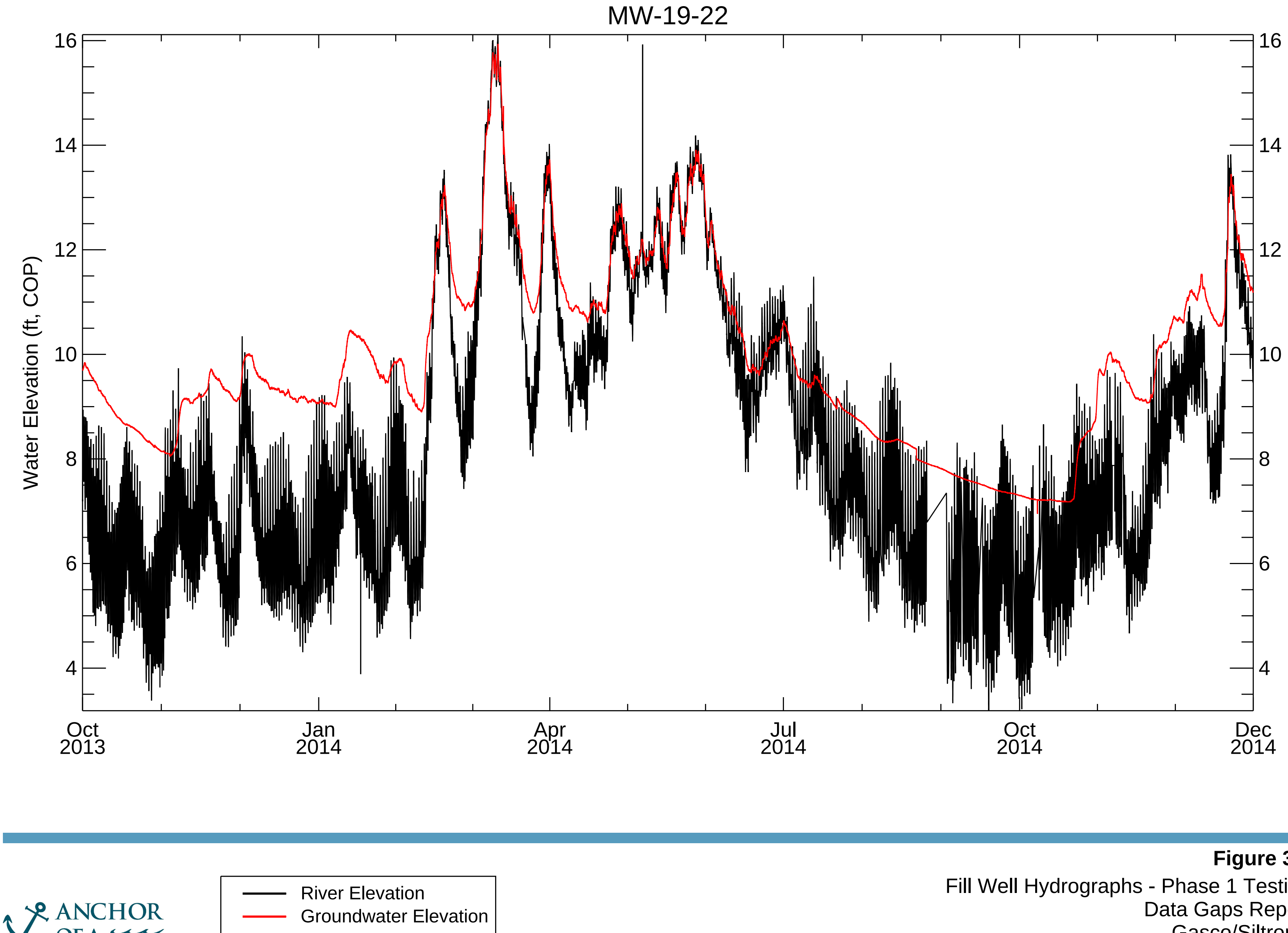

Figure 3.2
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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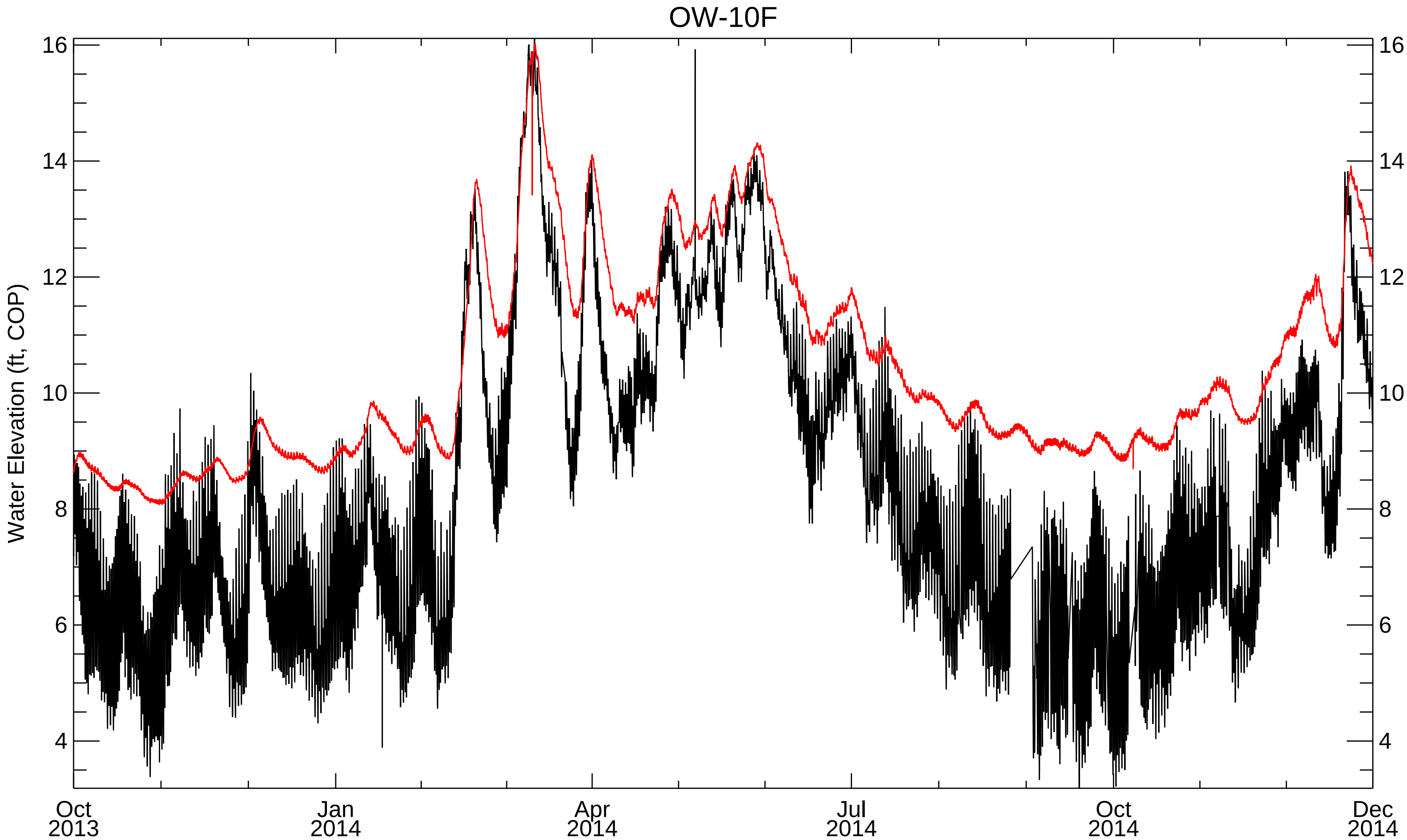

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Figure 3.3
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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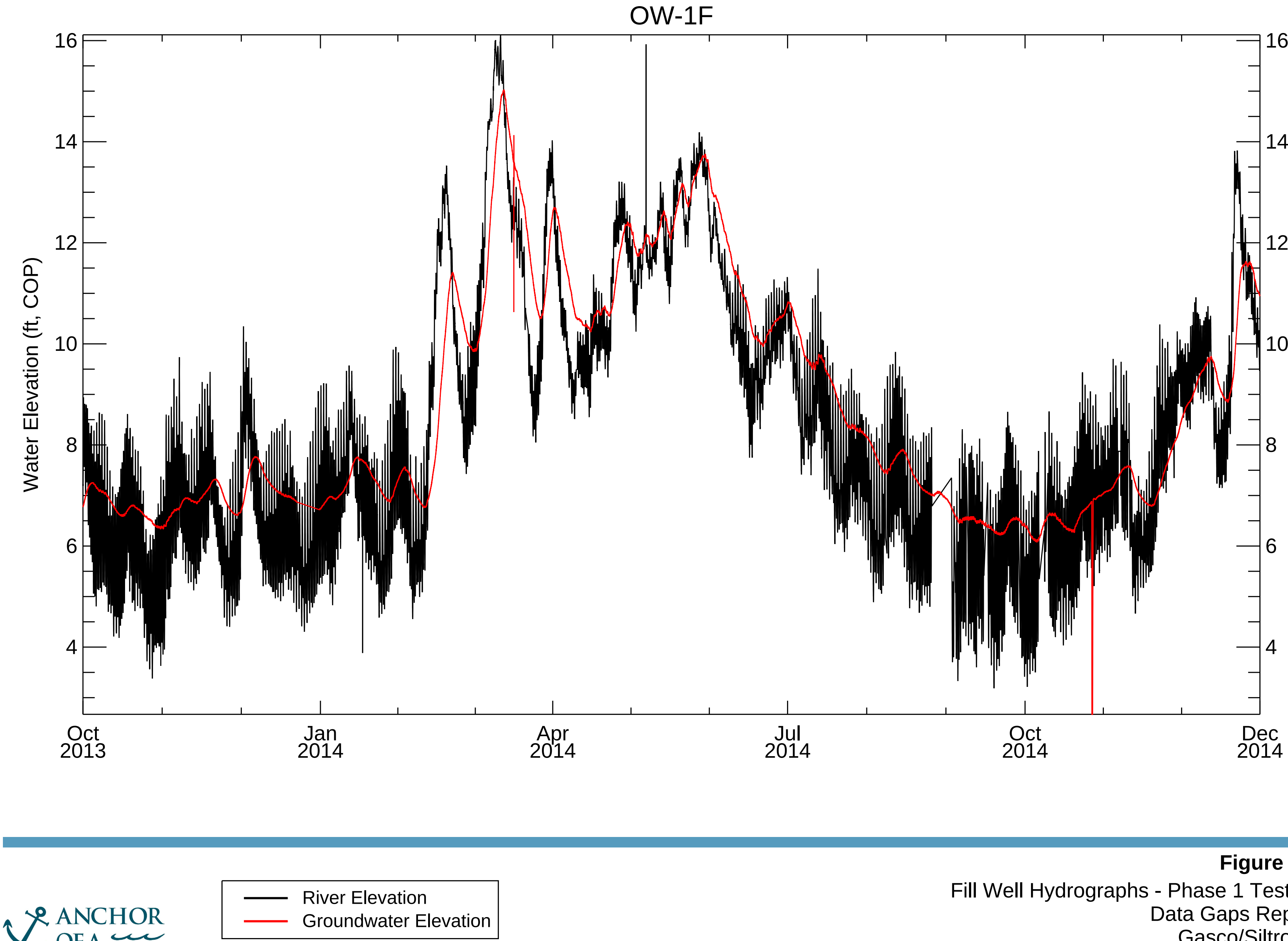

Figure 3.4

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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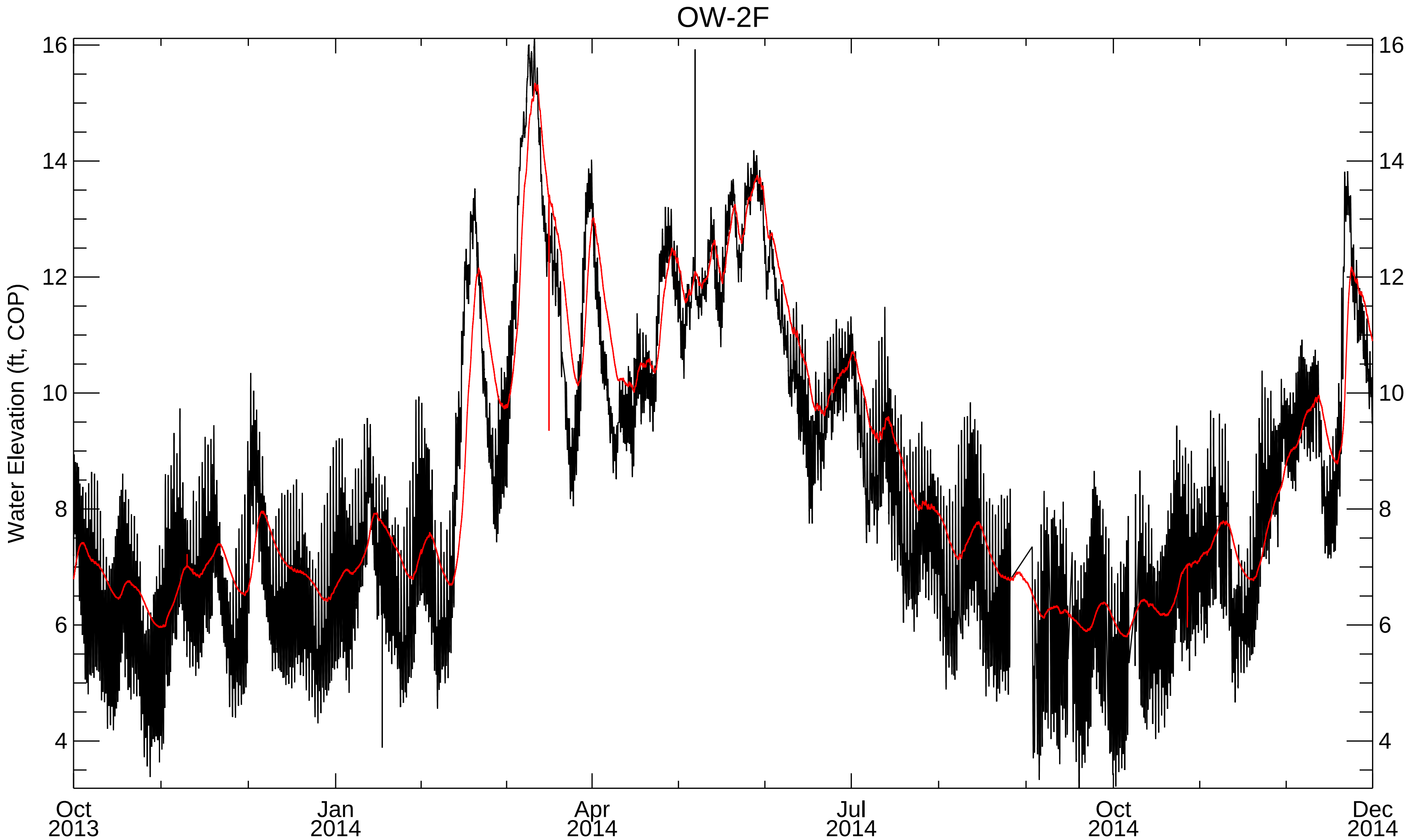

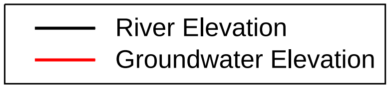

Figure 3.5

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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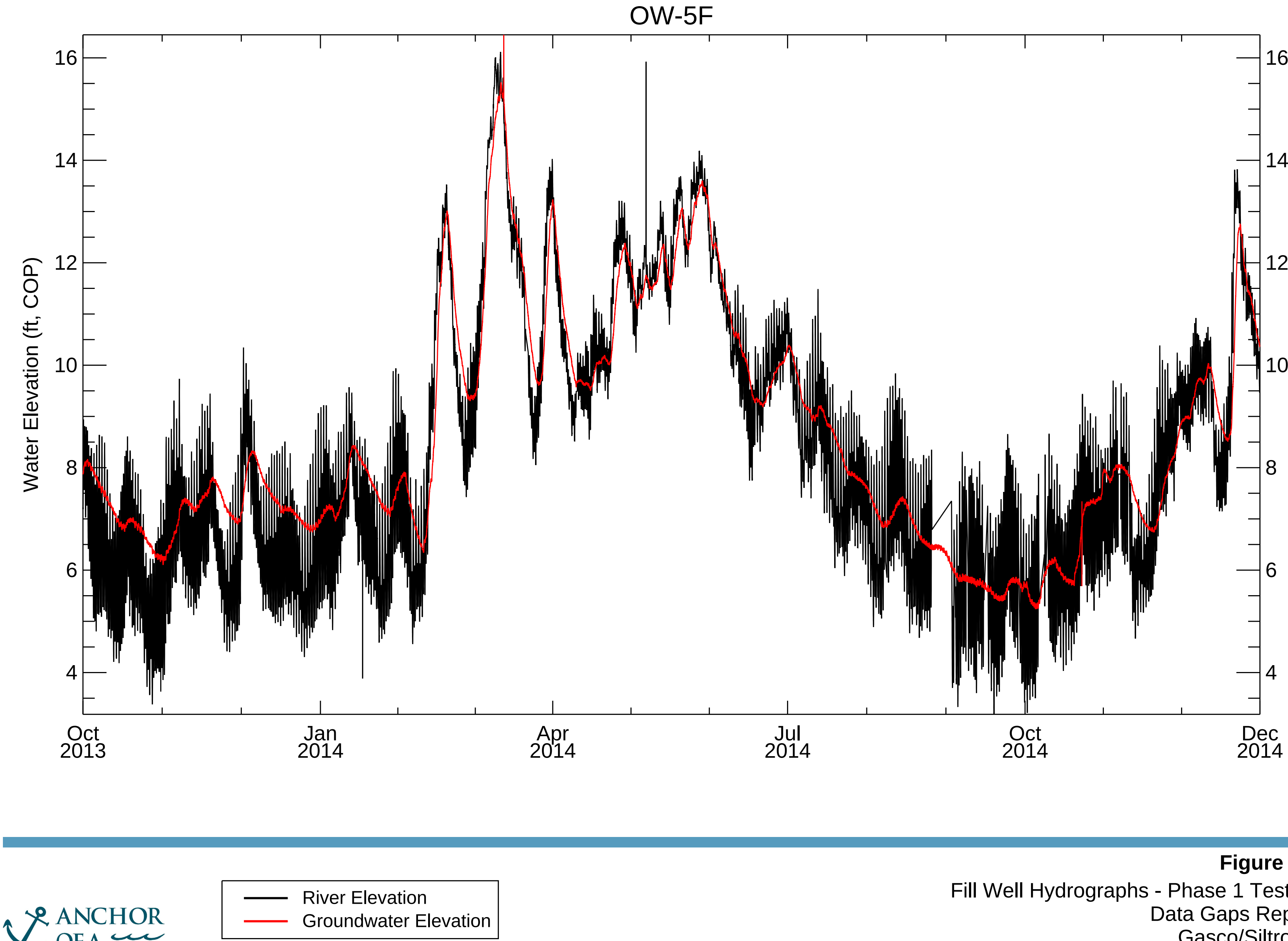

Figure 3.6

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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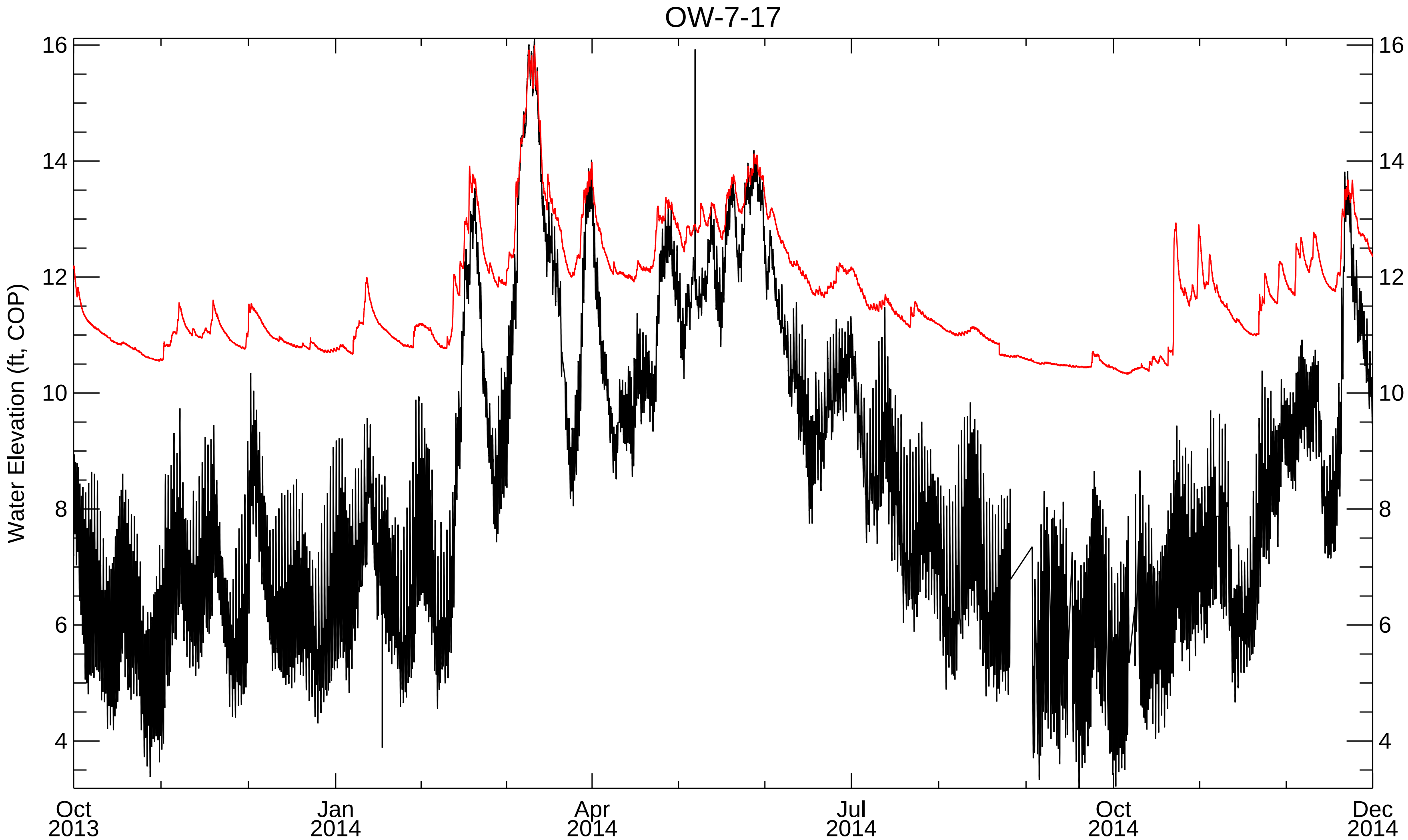

Figure 3.7

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

Fill

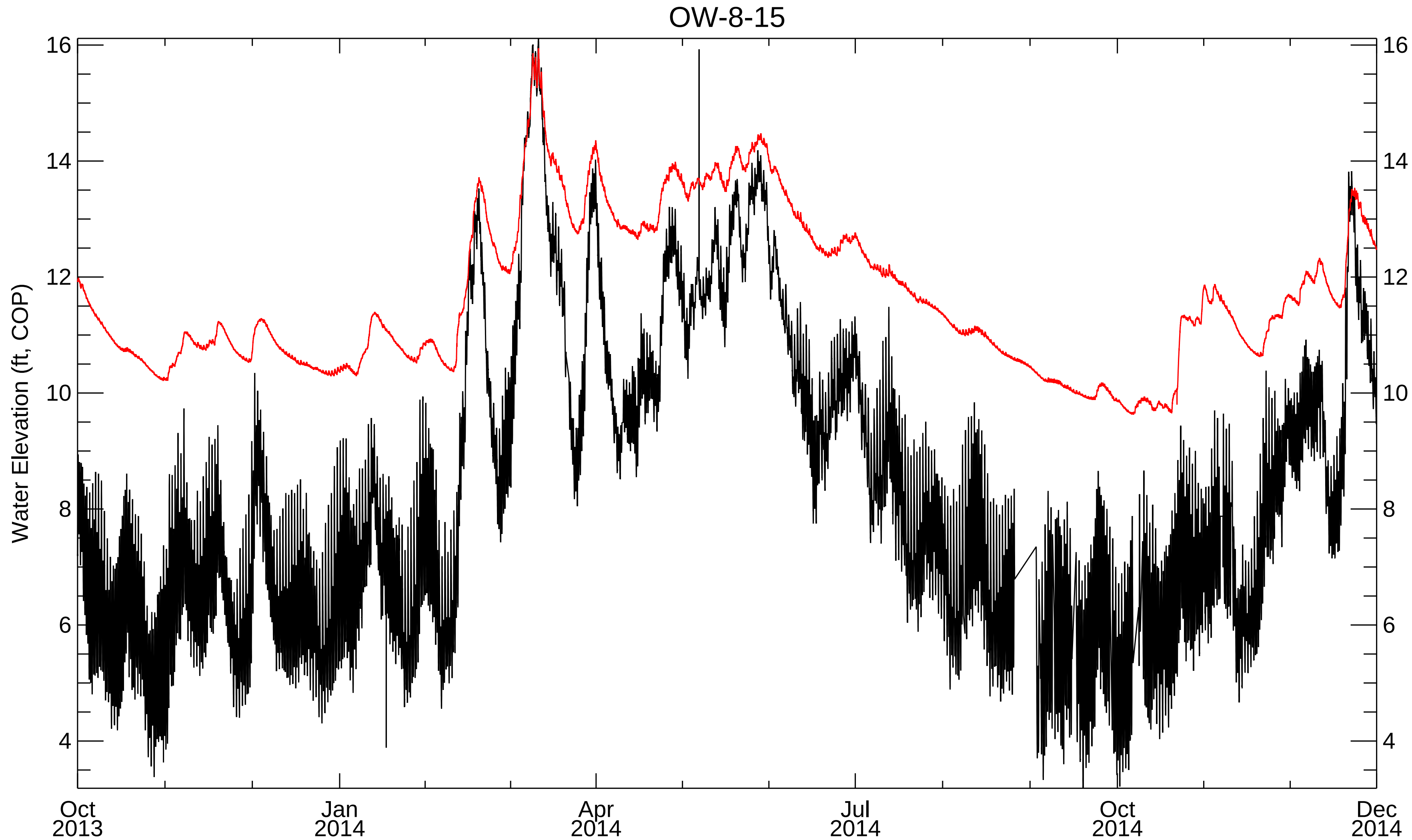

Figure 3.8

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

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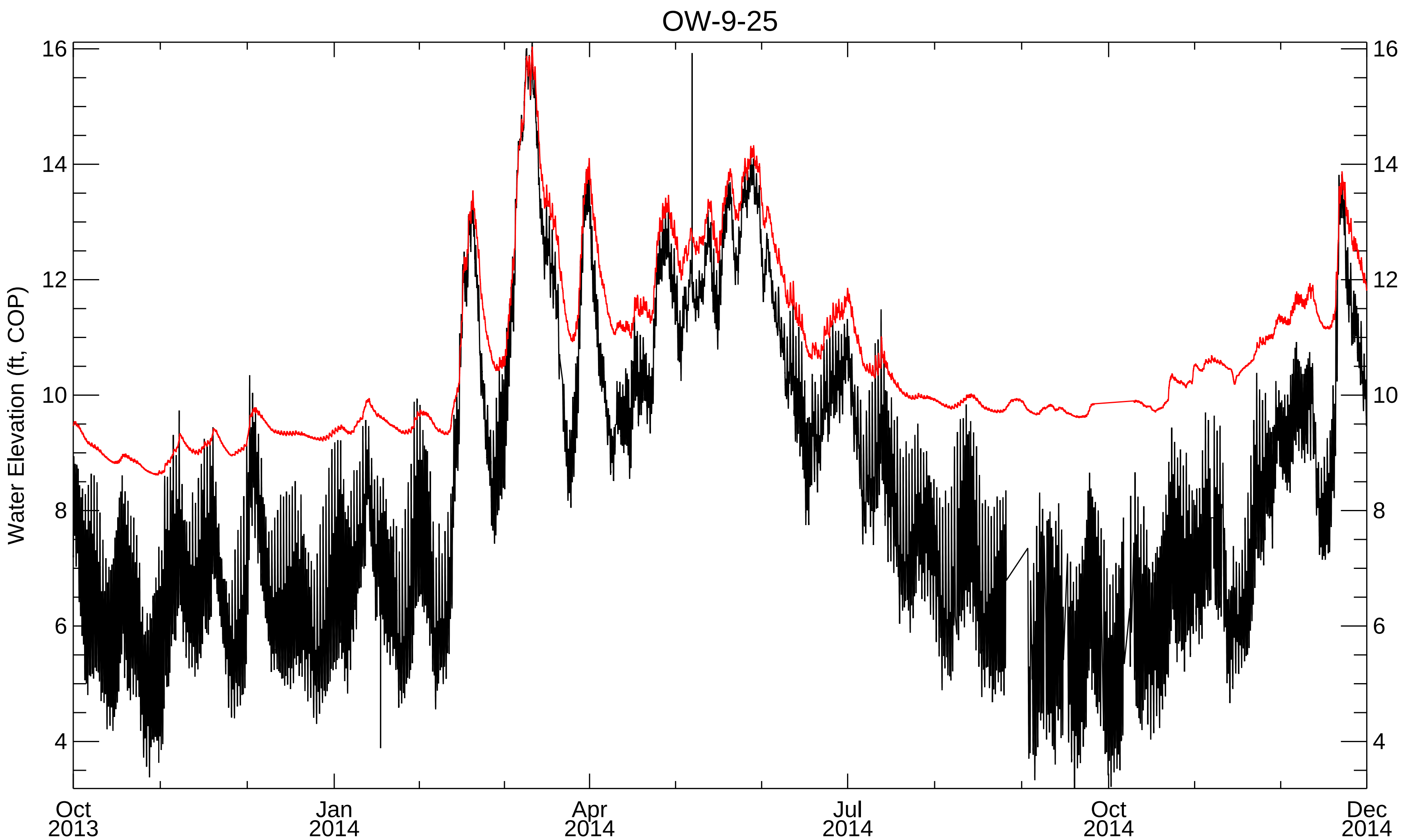
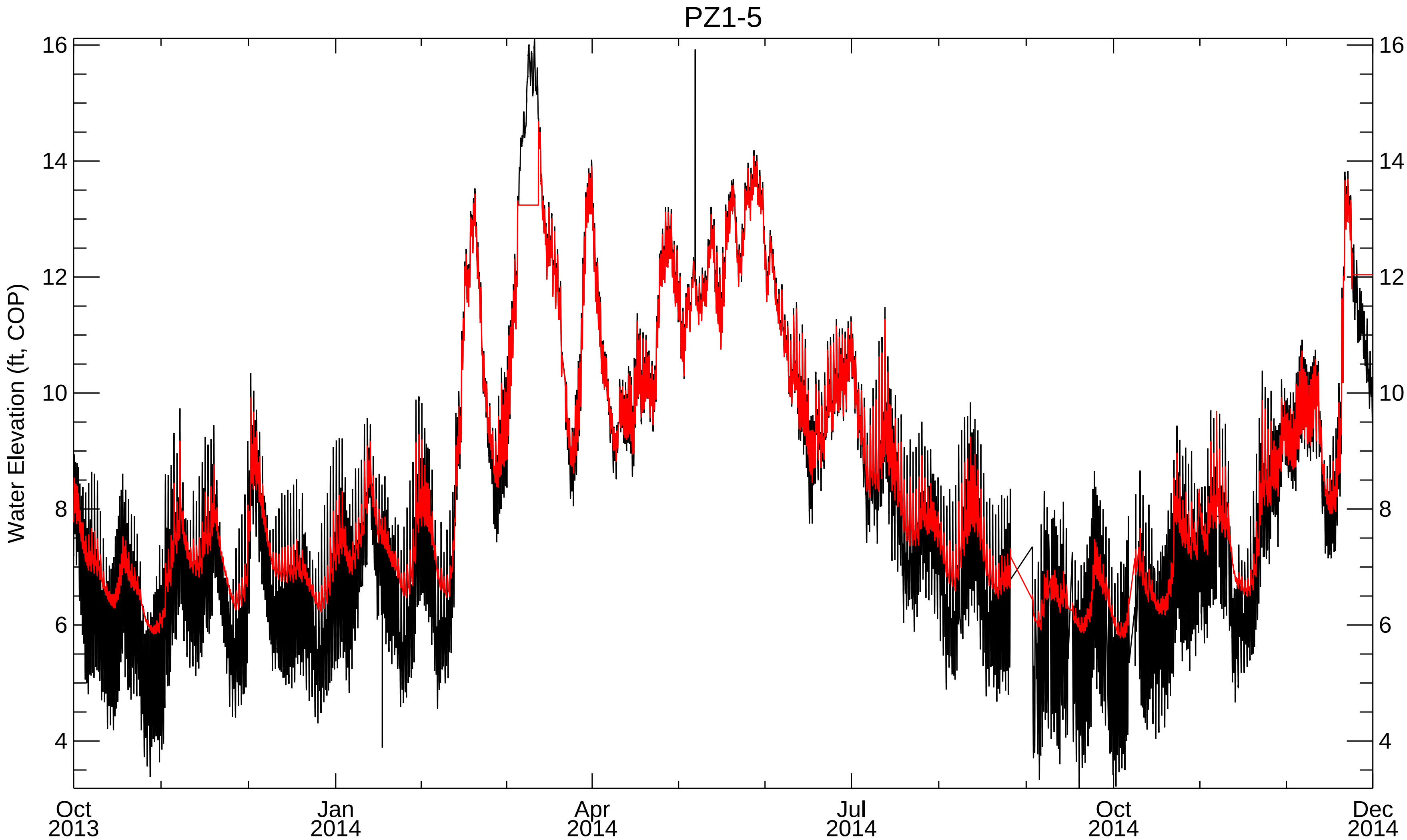


River Elevation
Groundwater Elevation

Figure 3.9

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

Fill



ANCHOR QEA

Figure 3.10
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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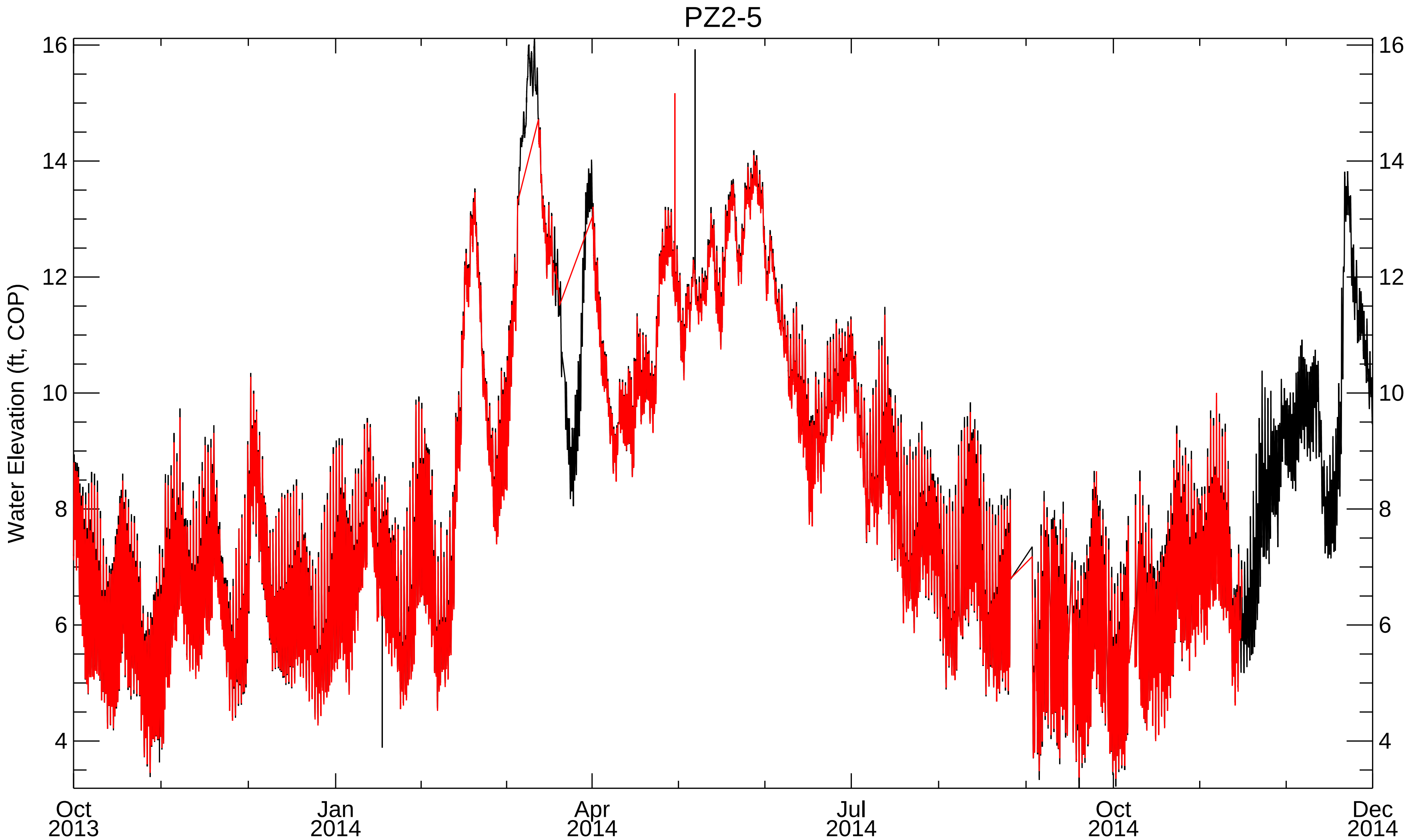

River Elevation
Groundwater Elevation

Figure 3.11

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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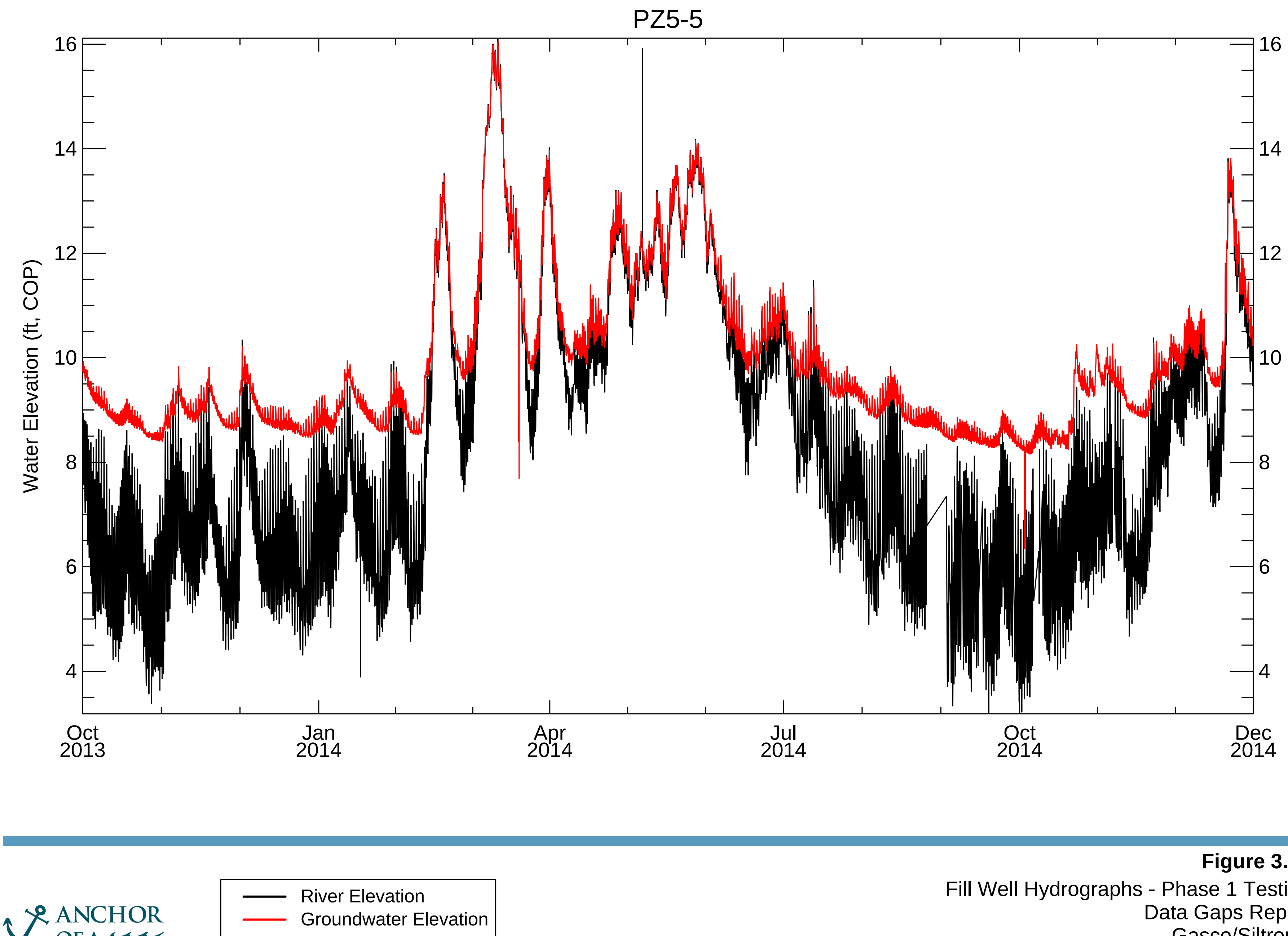

Figure 3.12

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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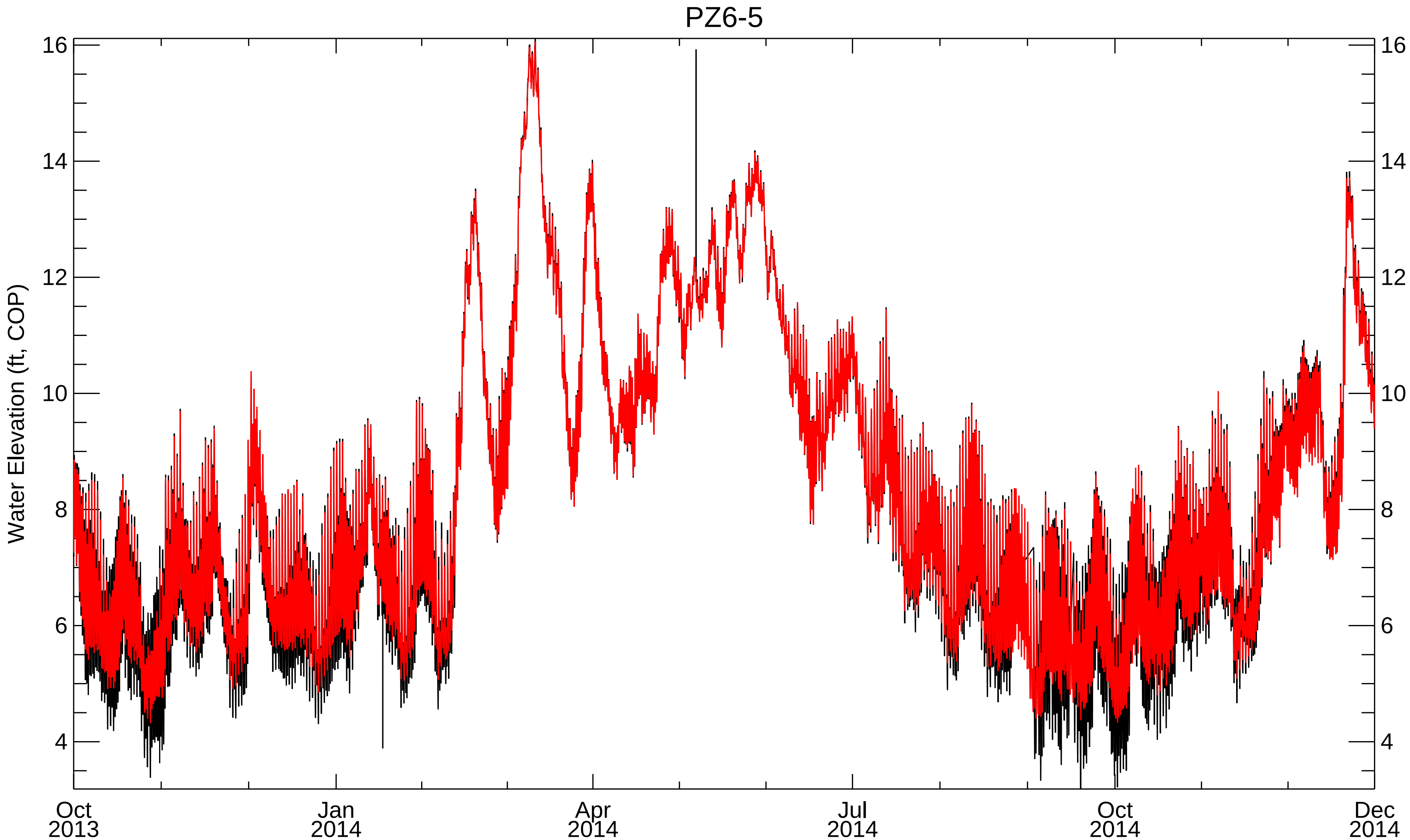

River Elevation
Groundwater Elevation

Figure 3.13

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:25:05 2015

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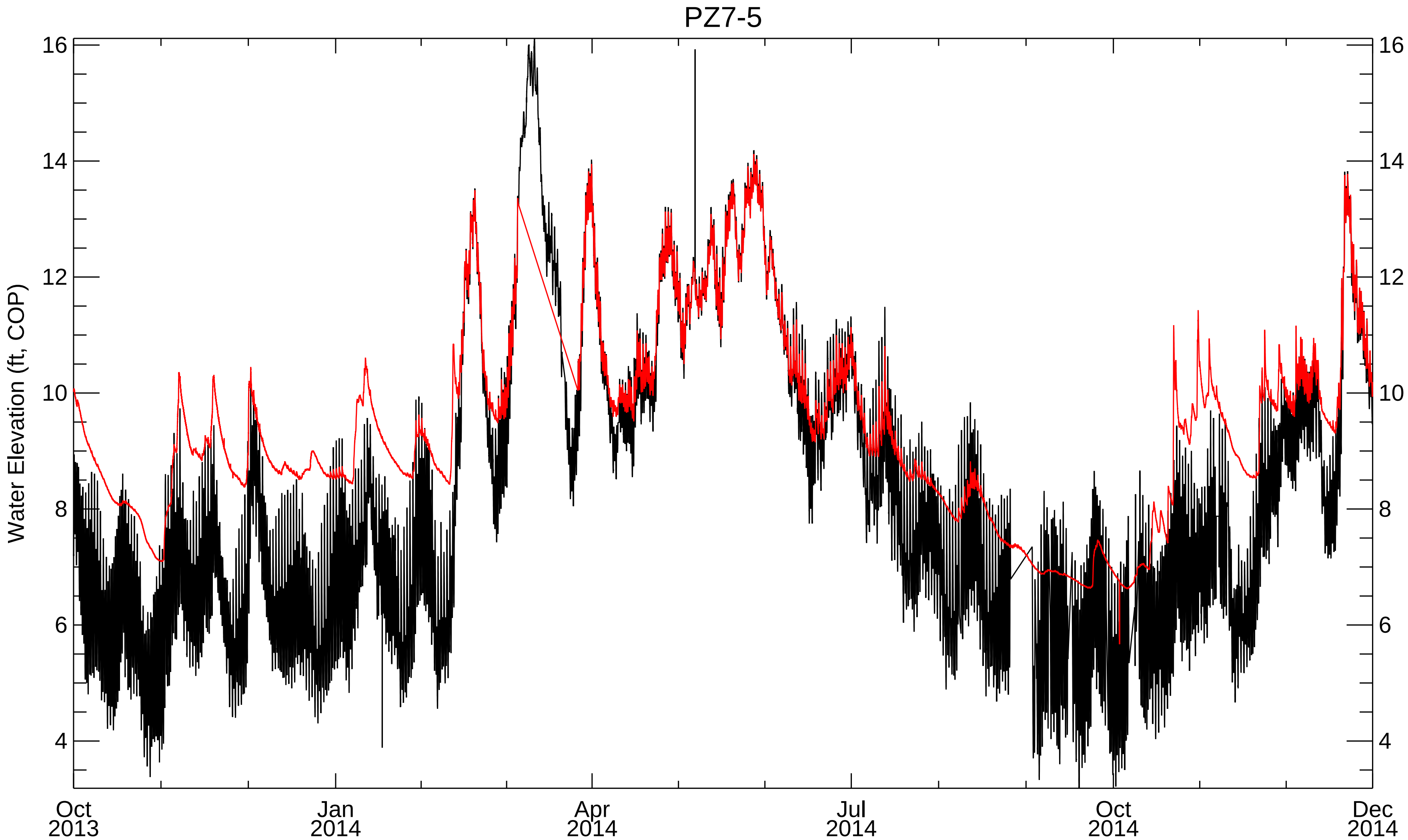

Figure 3.14
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

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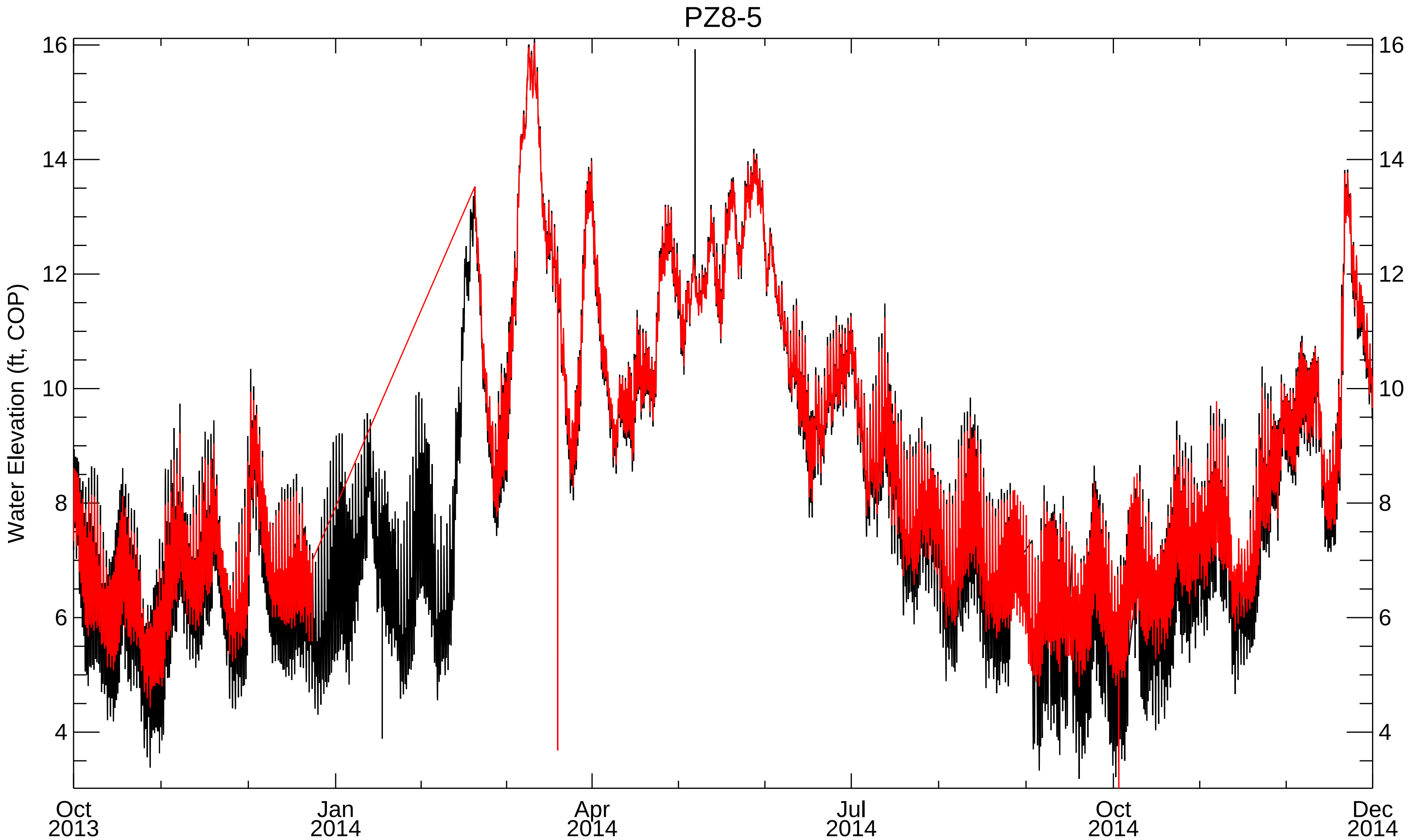

River Elevation
Groundwater Elevation

Figure 3.15
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

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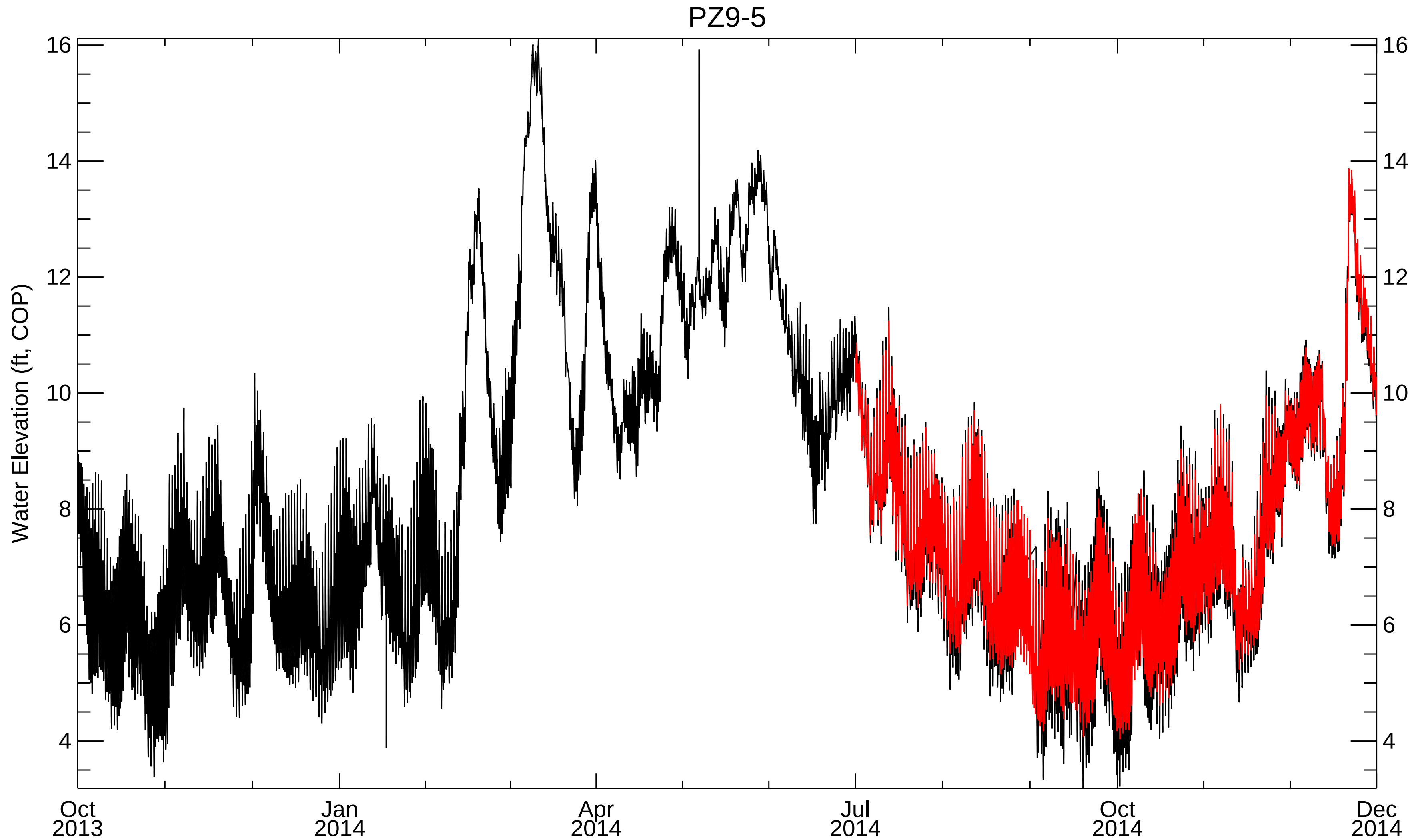

Figure 3.16

Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

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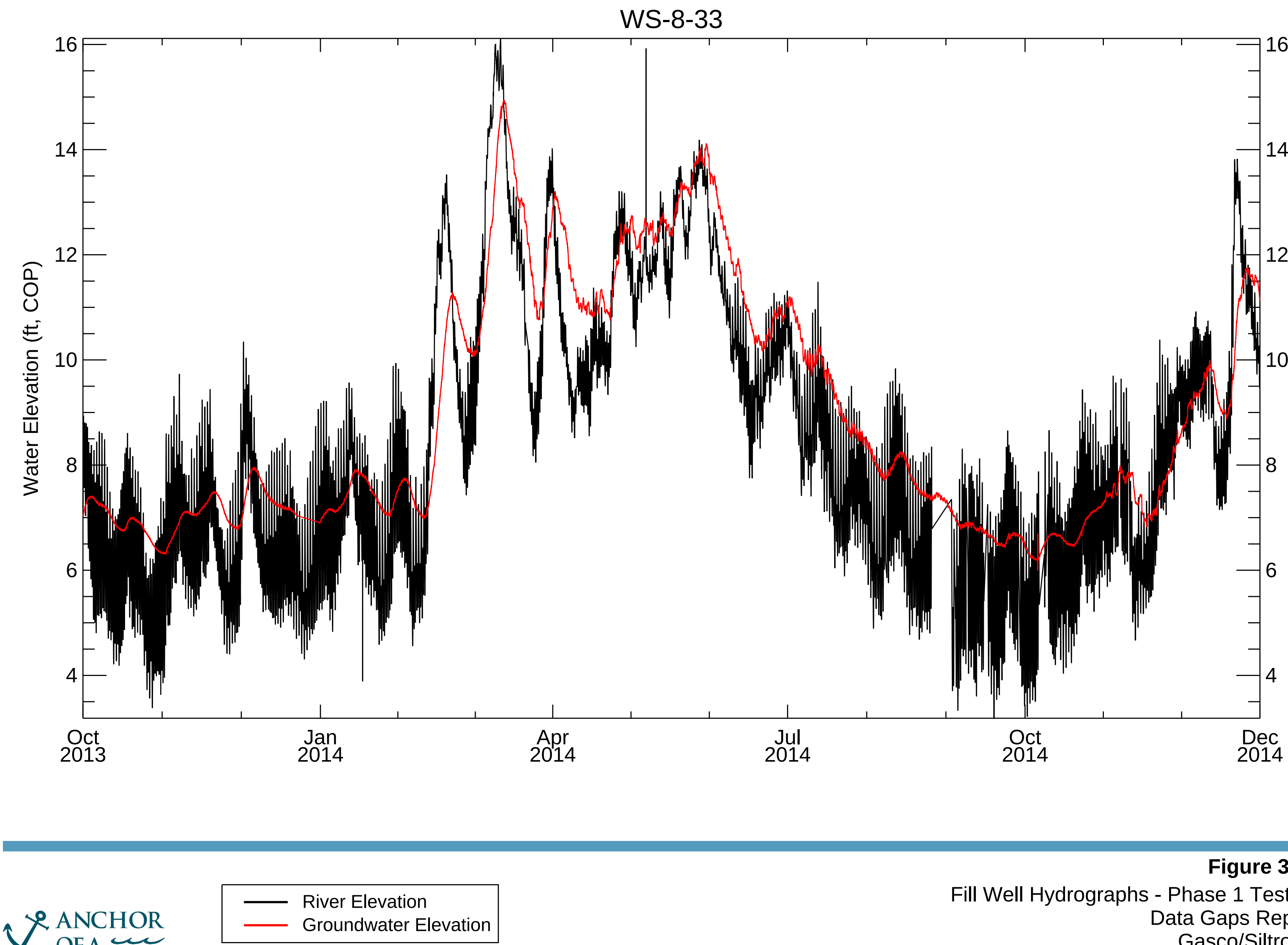

Figure 3.17
Fill Well Hydrographs - Phase 1 Testing
Data Gaps Report
Gasco/Siltronic

Fill

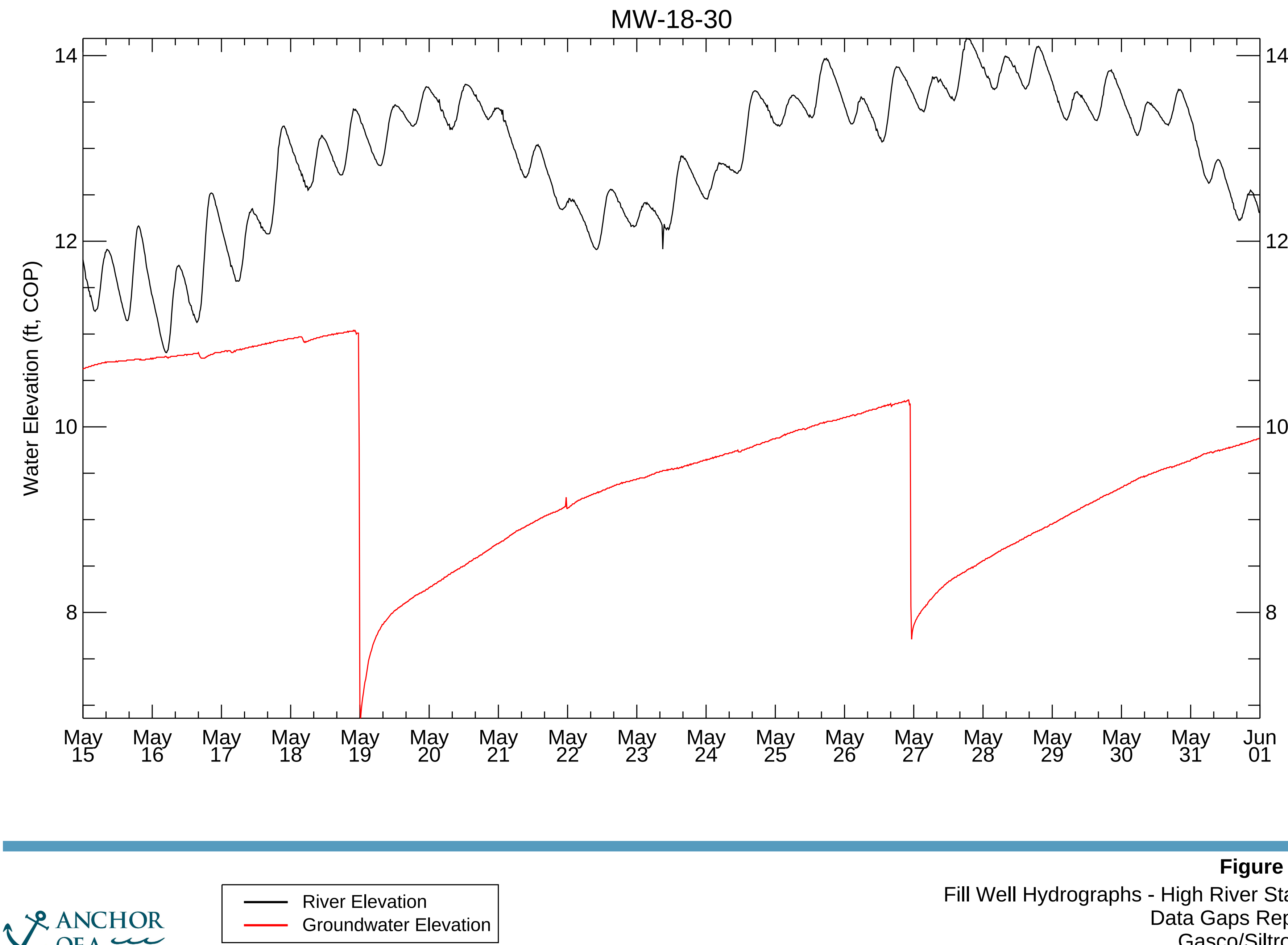

Figure 4.1

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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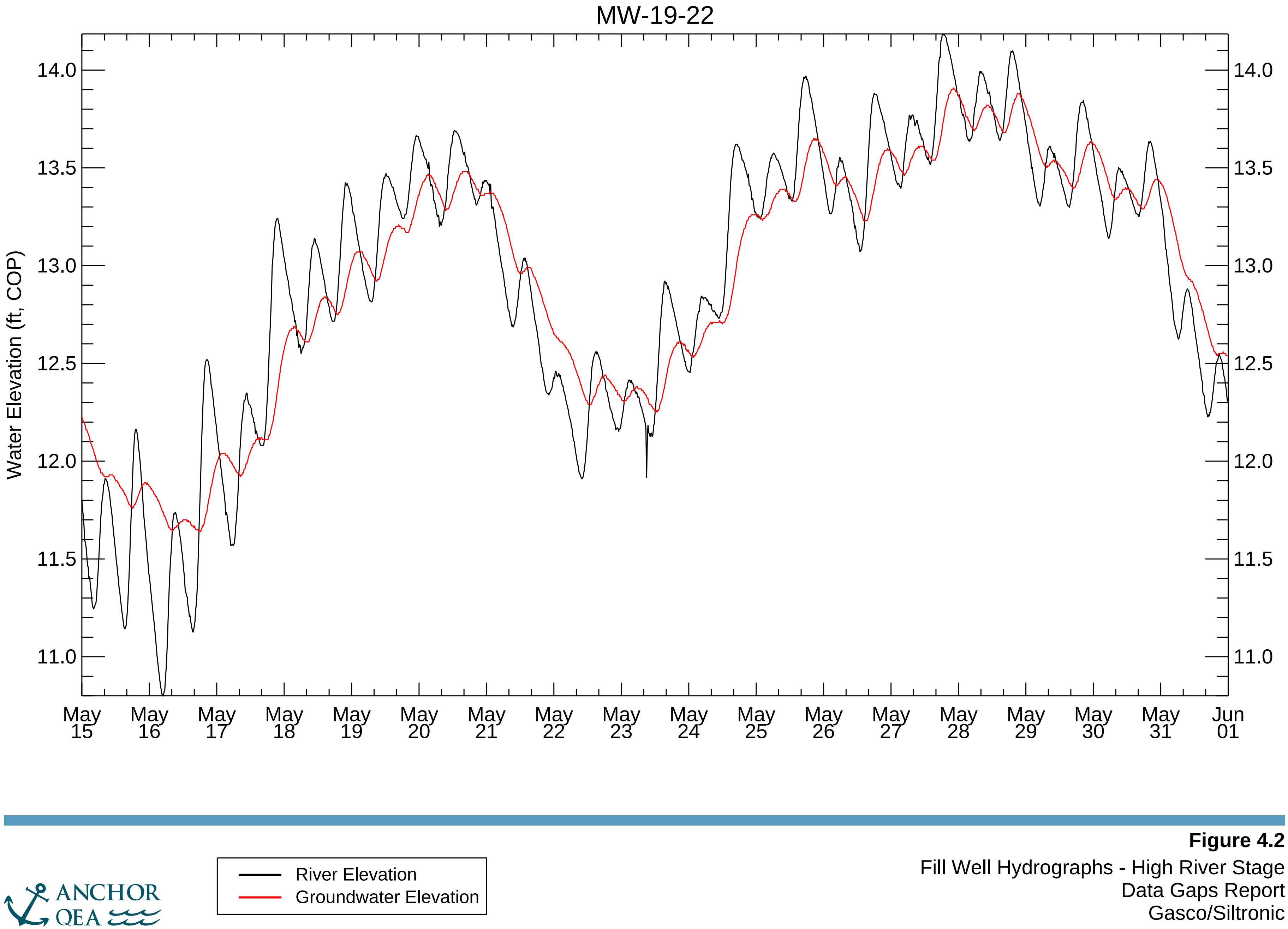

Figure 4.2

Fill Well Hydrographs - High River Stage

Data Gaps Report

Gasco/Siltronic

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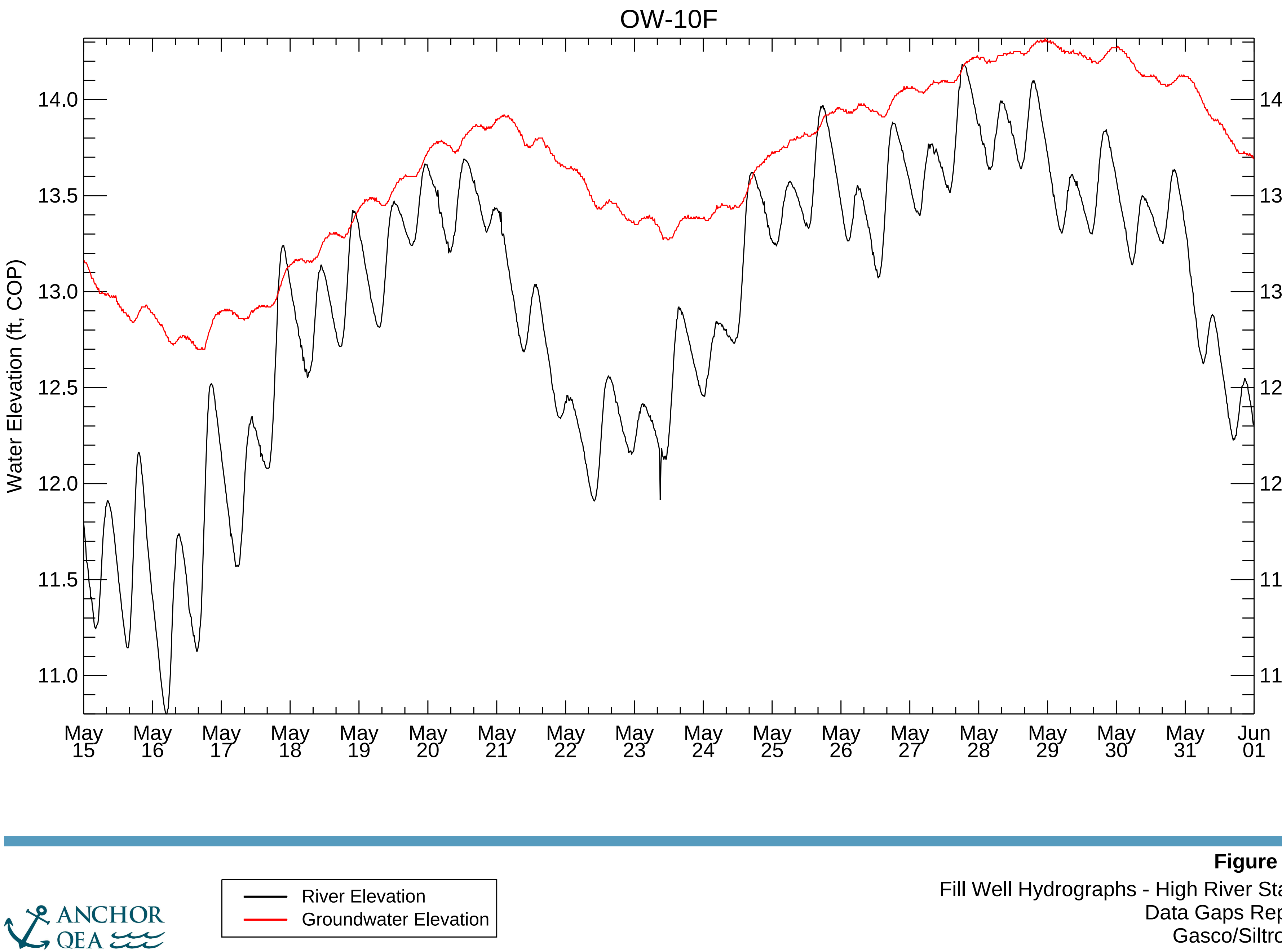

Figure 4.3

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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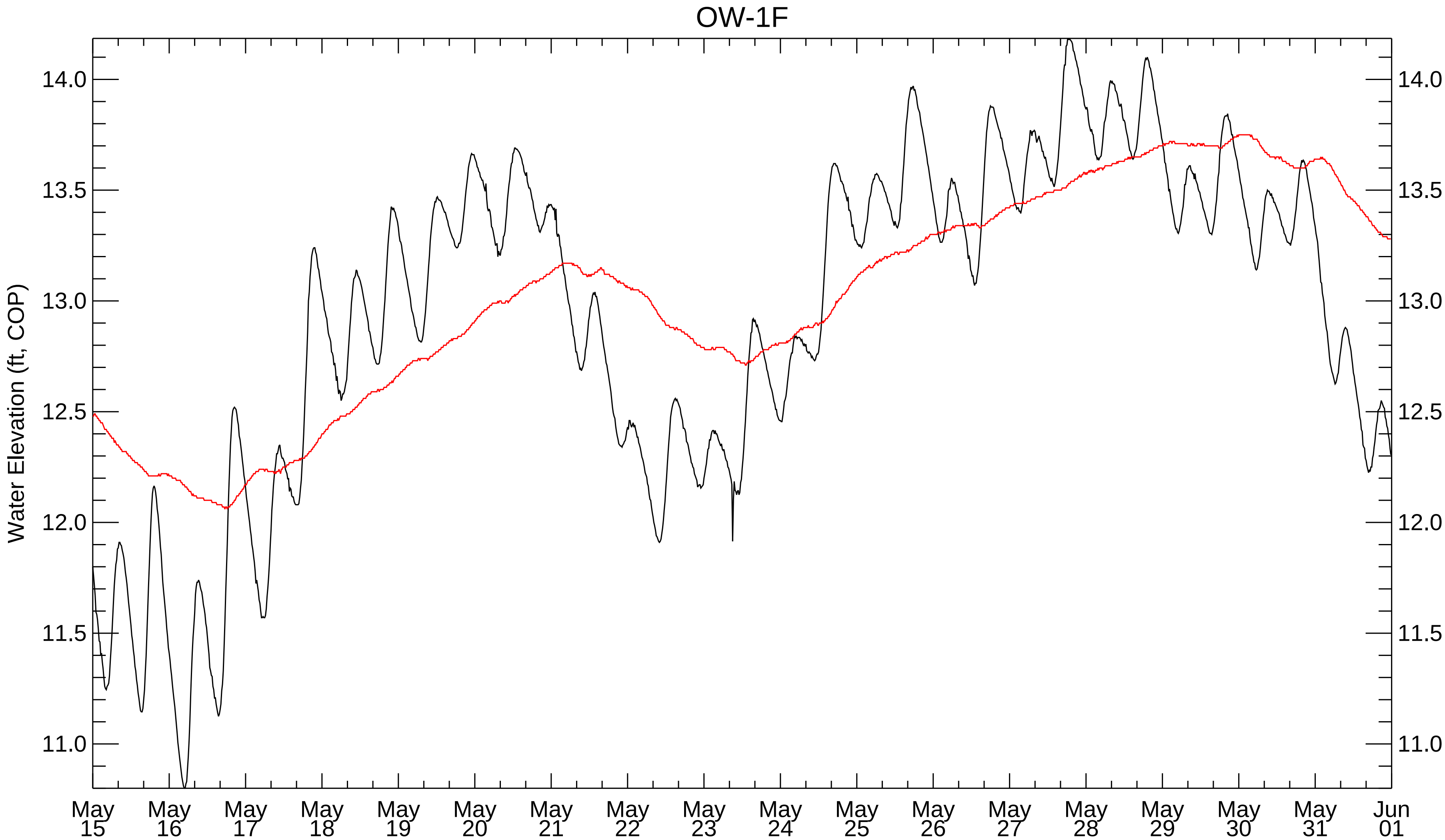

ANCHOR QEA

Figure 4.4

Fill Well Hydrographs - High River Stage

Data Gaps Report

Gasco/Siltronic

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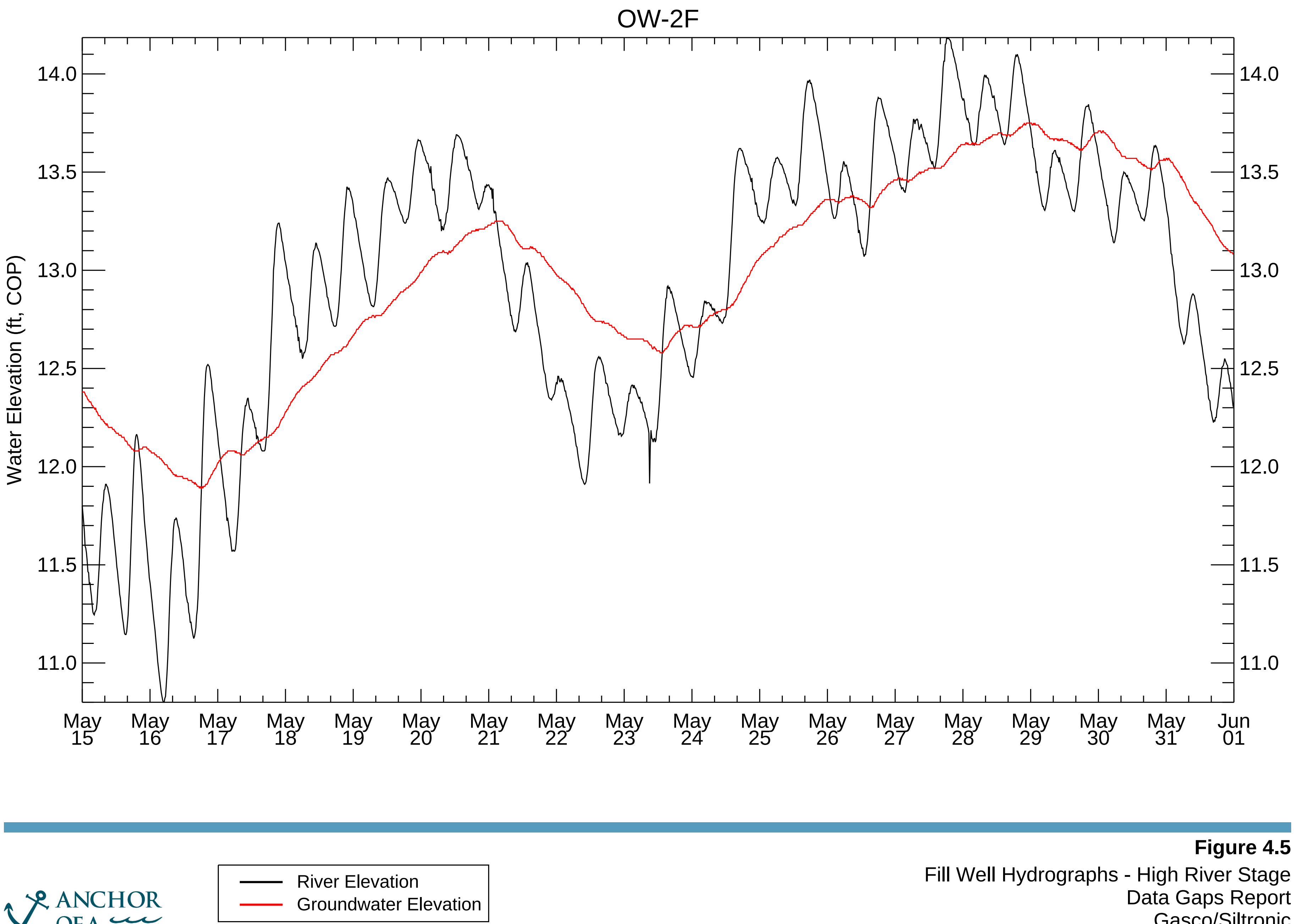

Figure 4.5

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

Fill

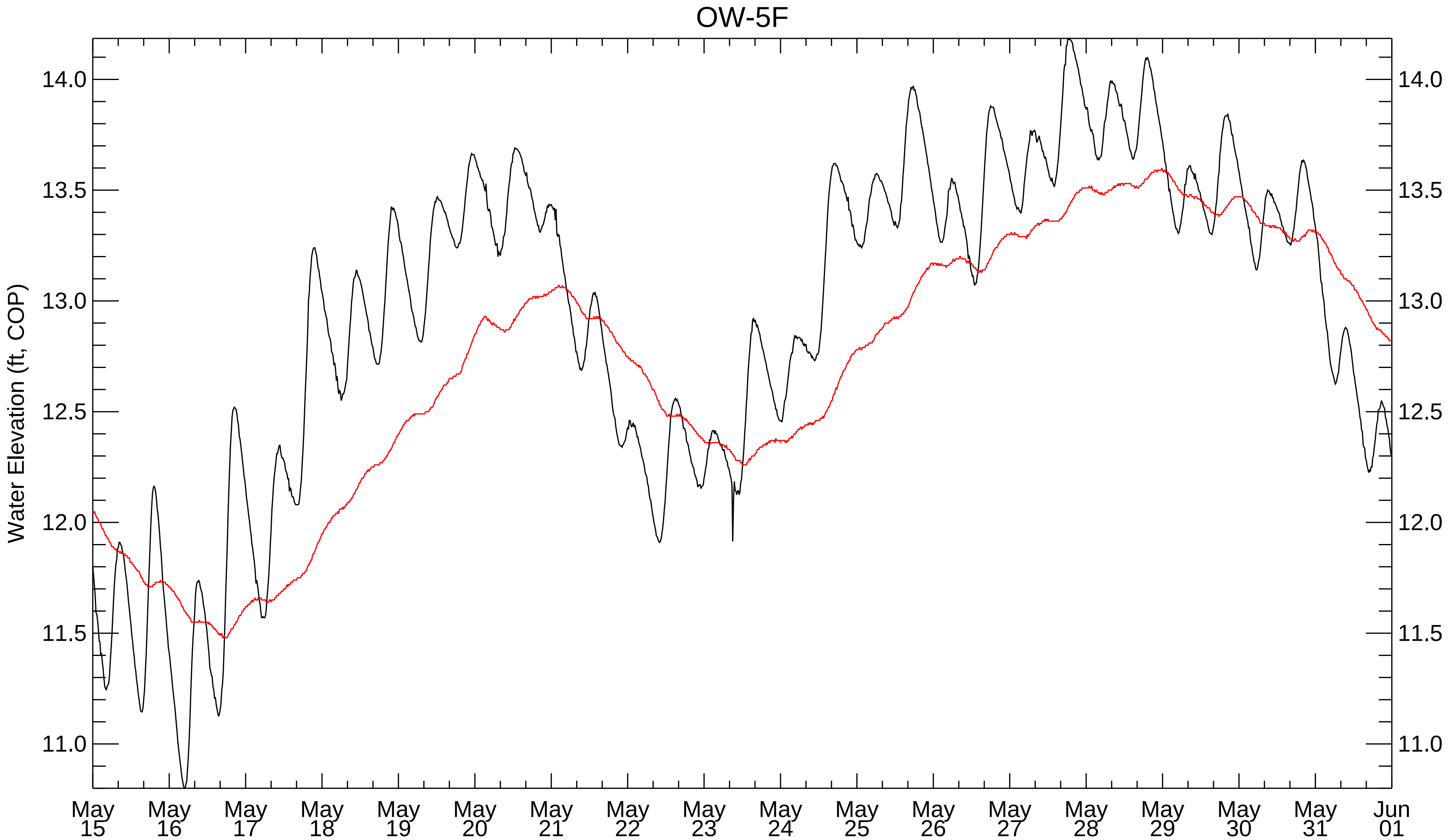

Figure 4.6

Fill Well Hydrographs - High River Stage

Data Gaps Report

Gasco/Siltronic

Fill

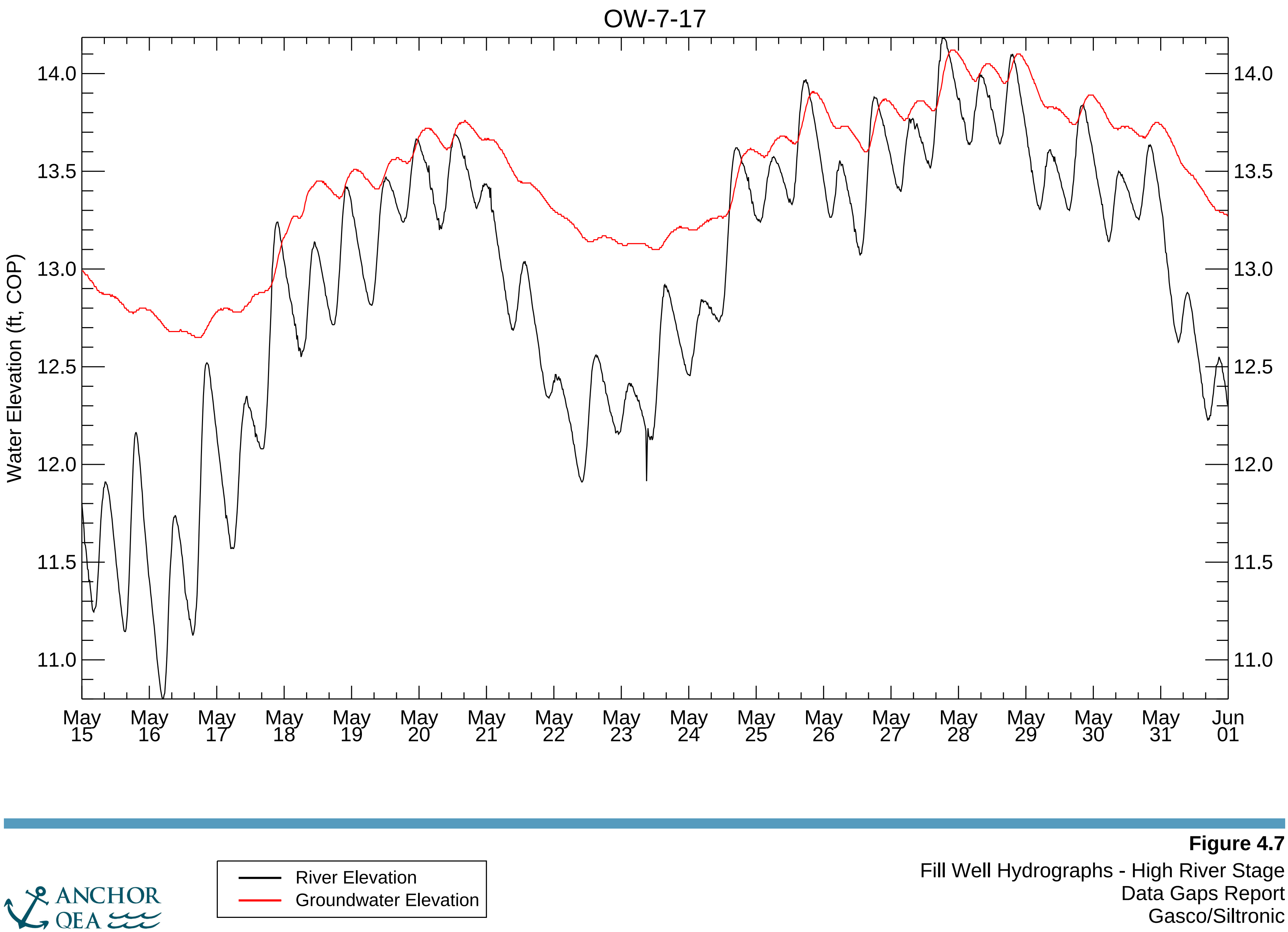

Figure 4.7

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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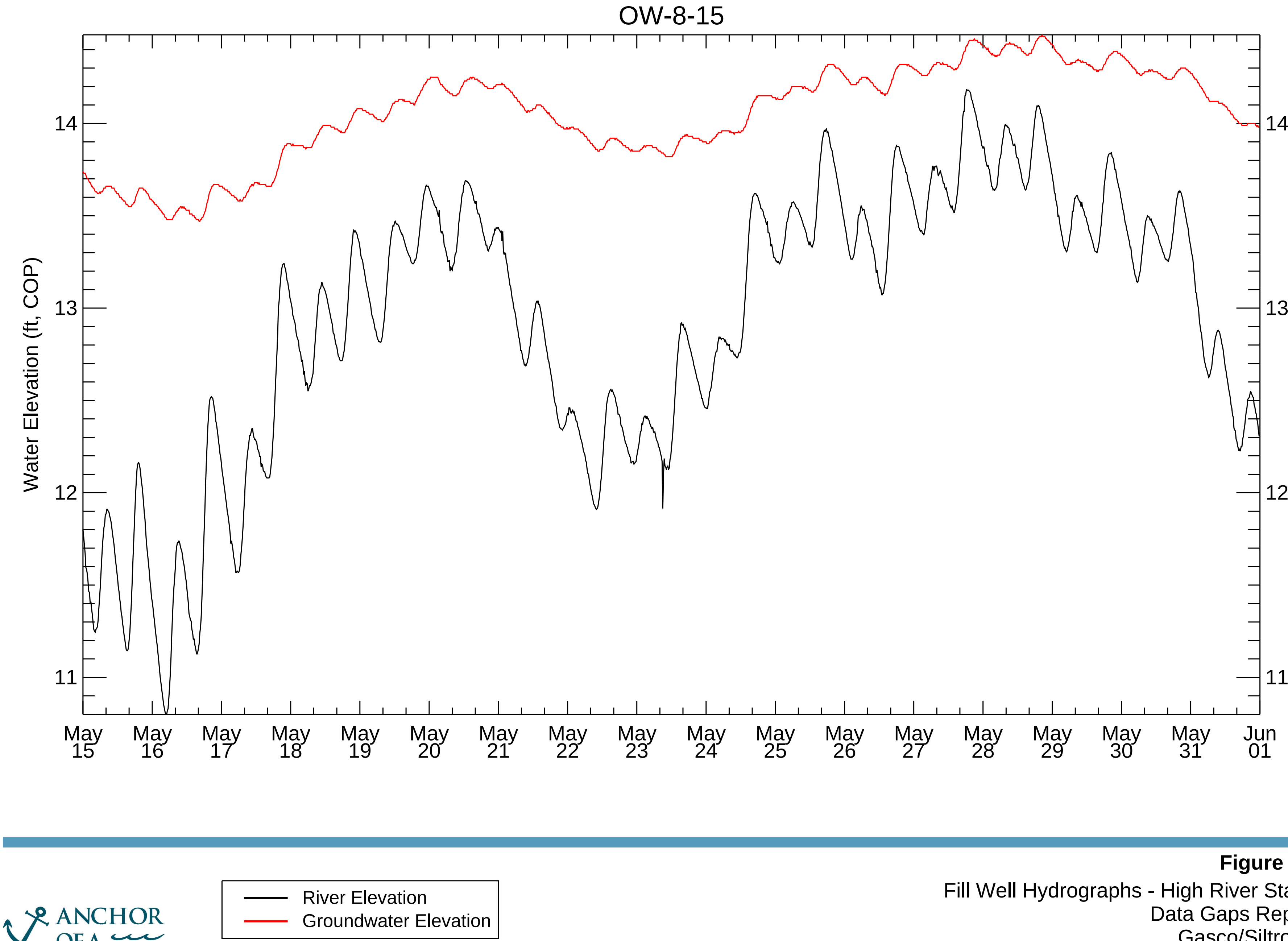

ANCHOR QEA

Figure 4.8

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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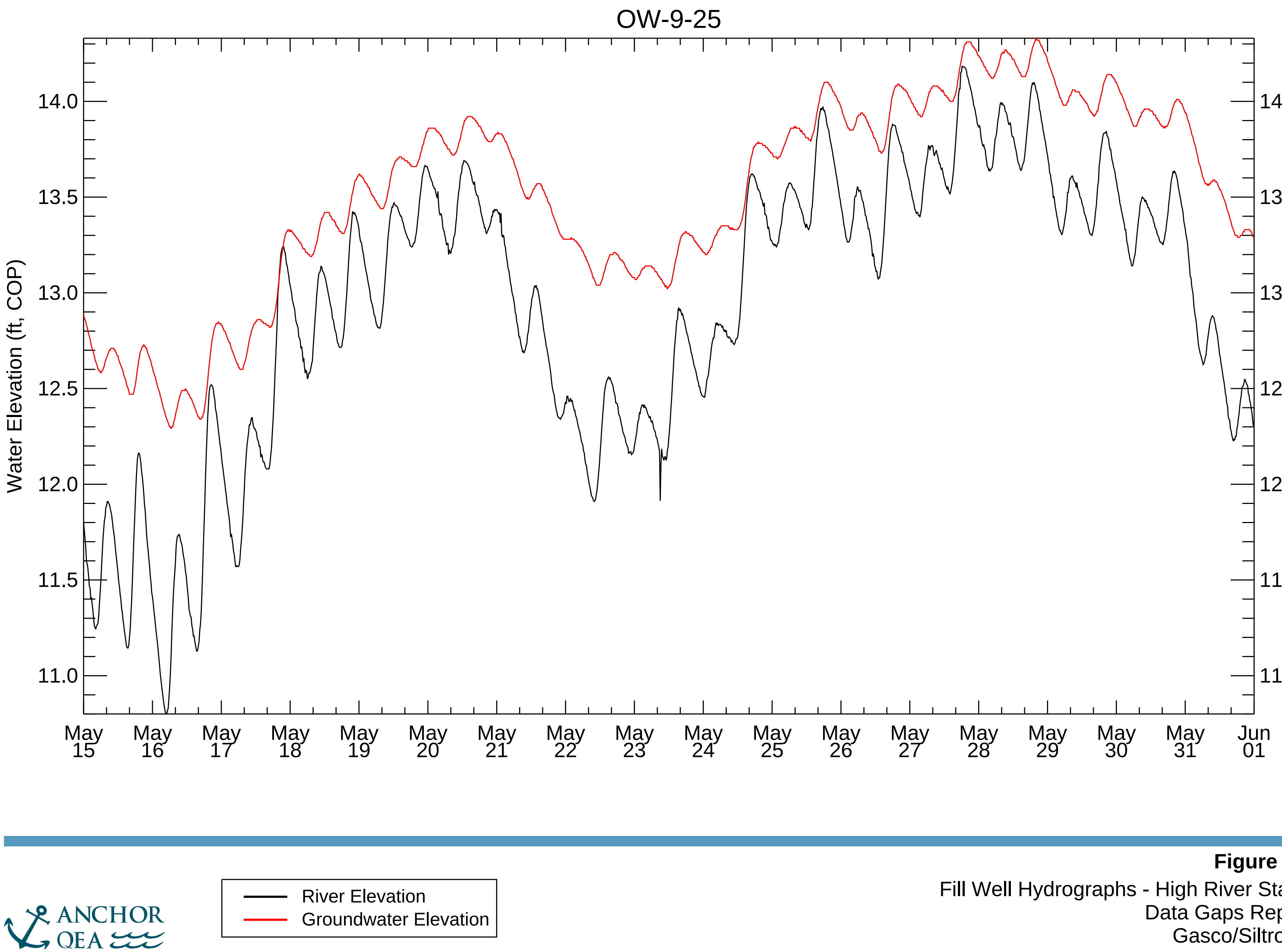

Figure 4.9

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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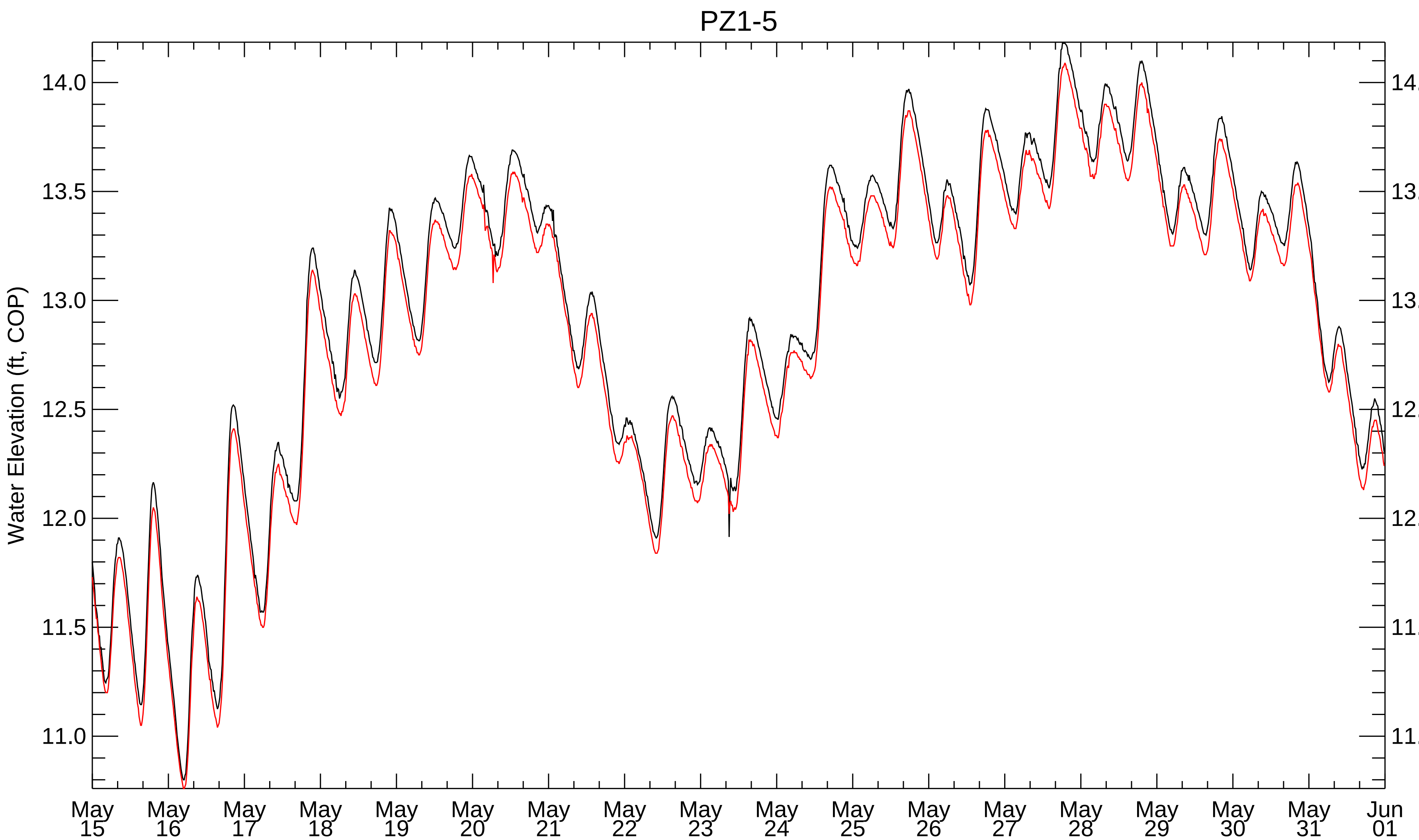

Figure 4.10
Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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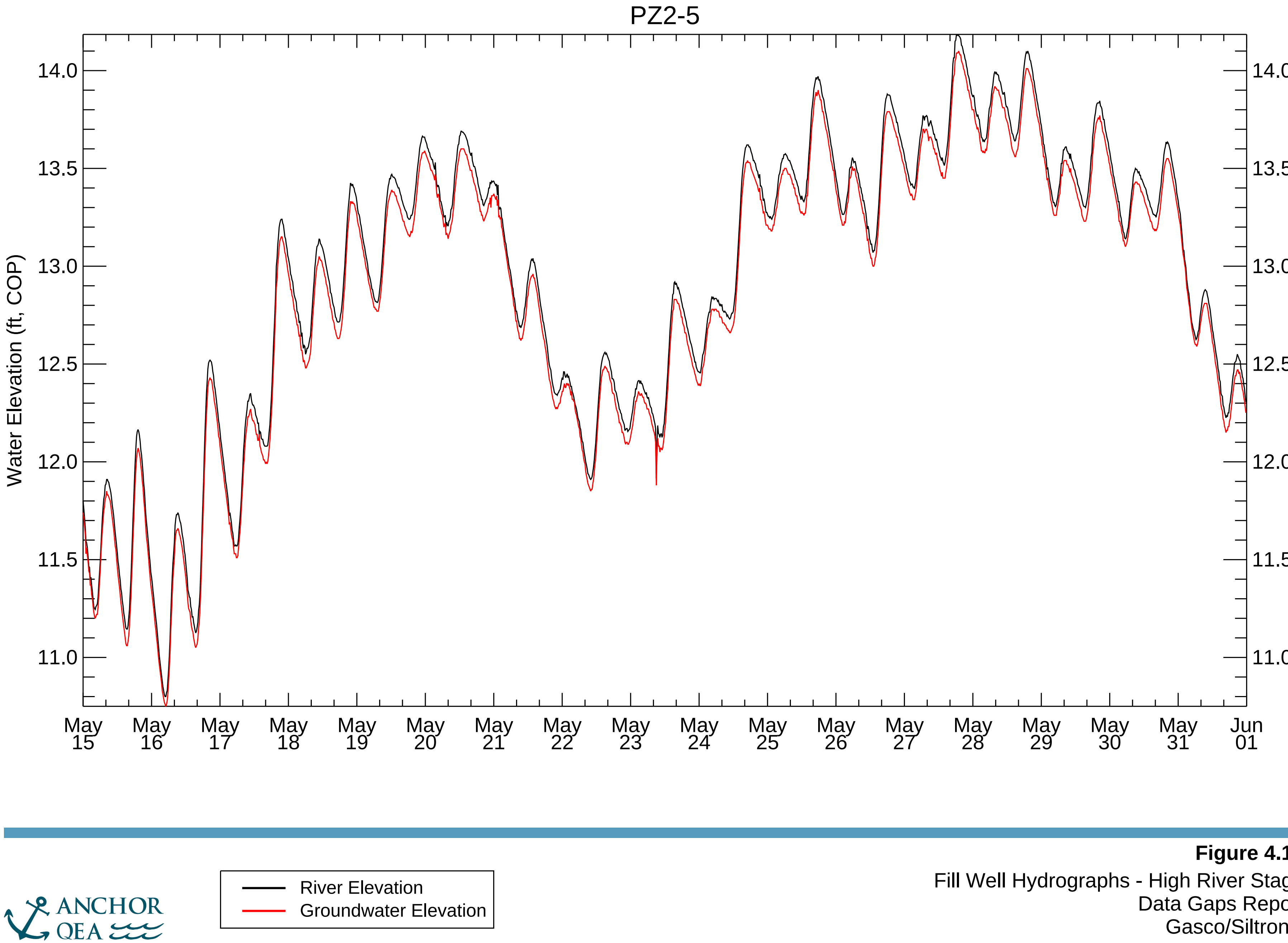

ANCHOR QEA

Figure 4.11

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:26:21 2015

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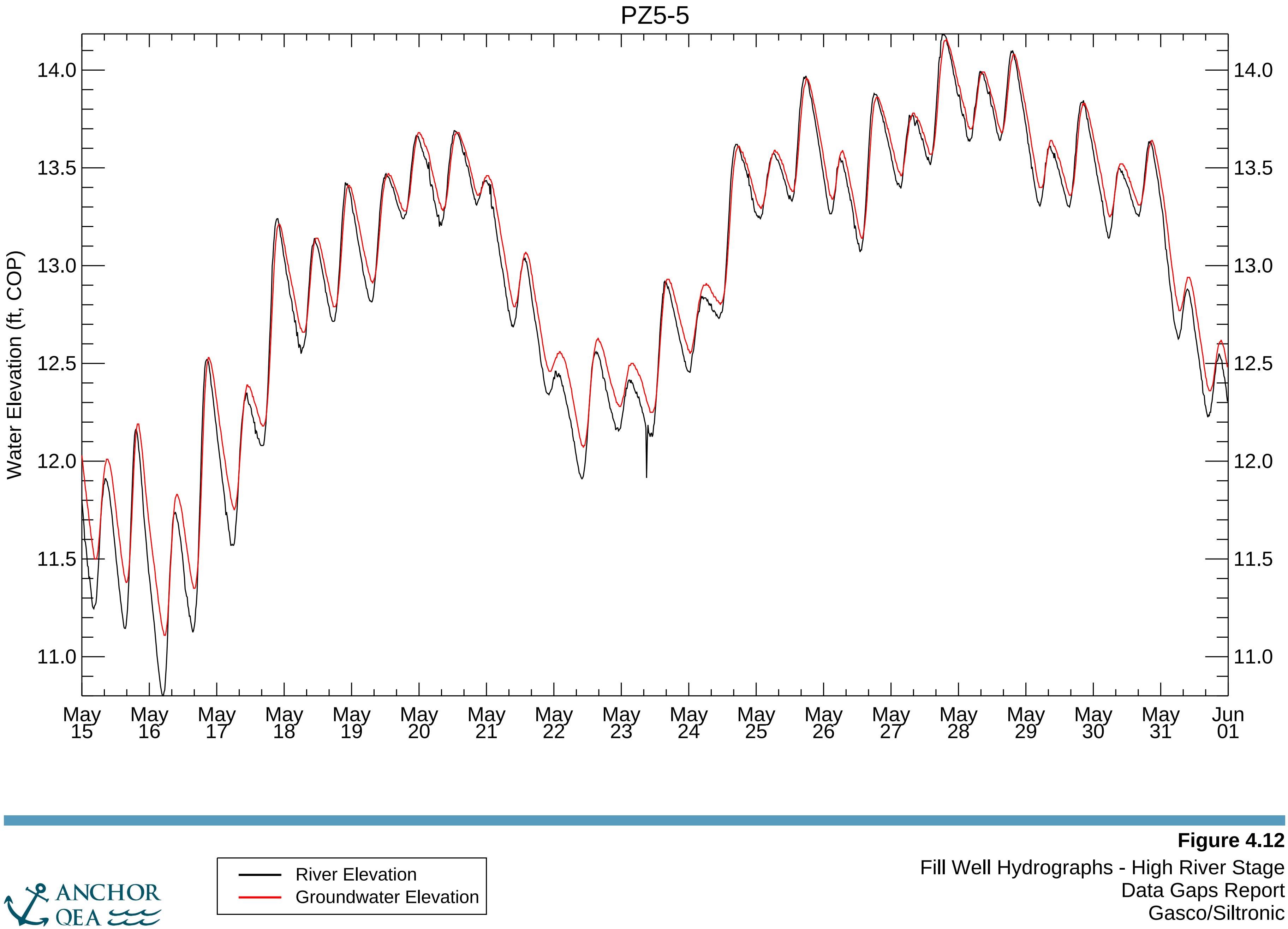

Figure 4.12
Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:26:21 2015

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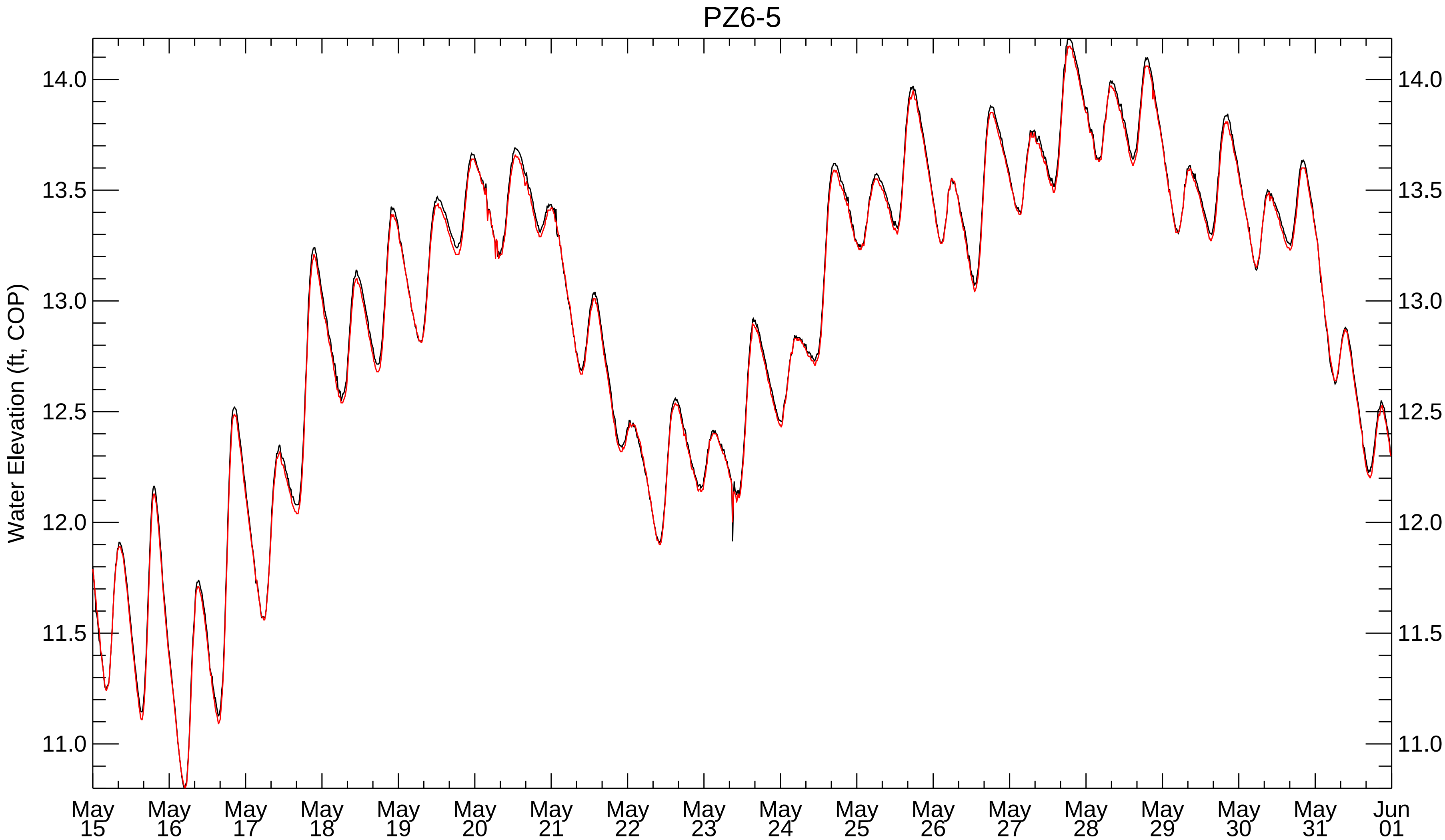

ANCHOR QEA

River Elevation
Groundwater Elevation

Figure 4.13

Fill Well Hydrographs - High River Stage

Data Gaps Report

Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:26:21 2015

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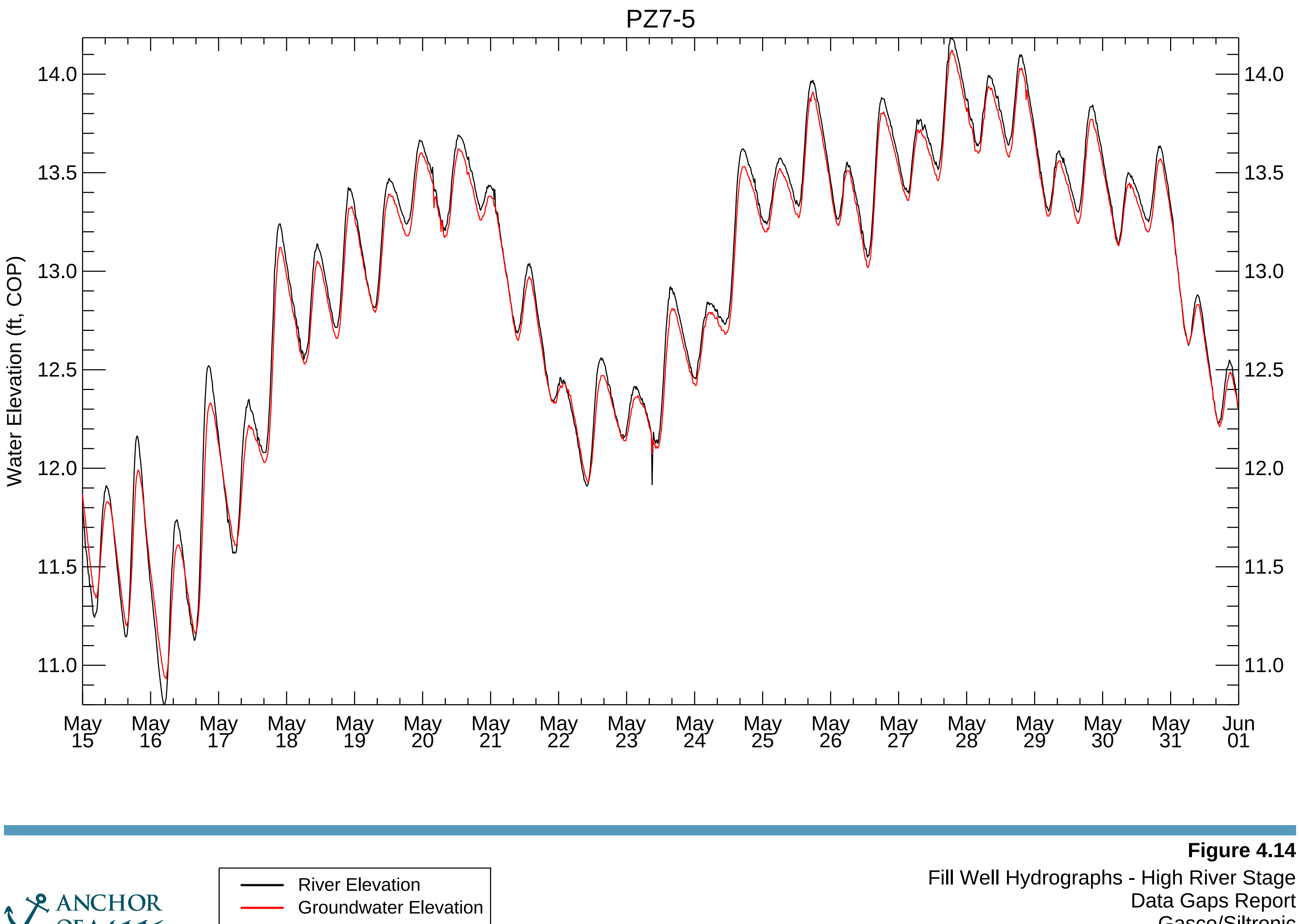

ANCHOR QEA

Figure 4.14
Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

Fill

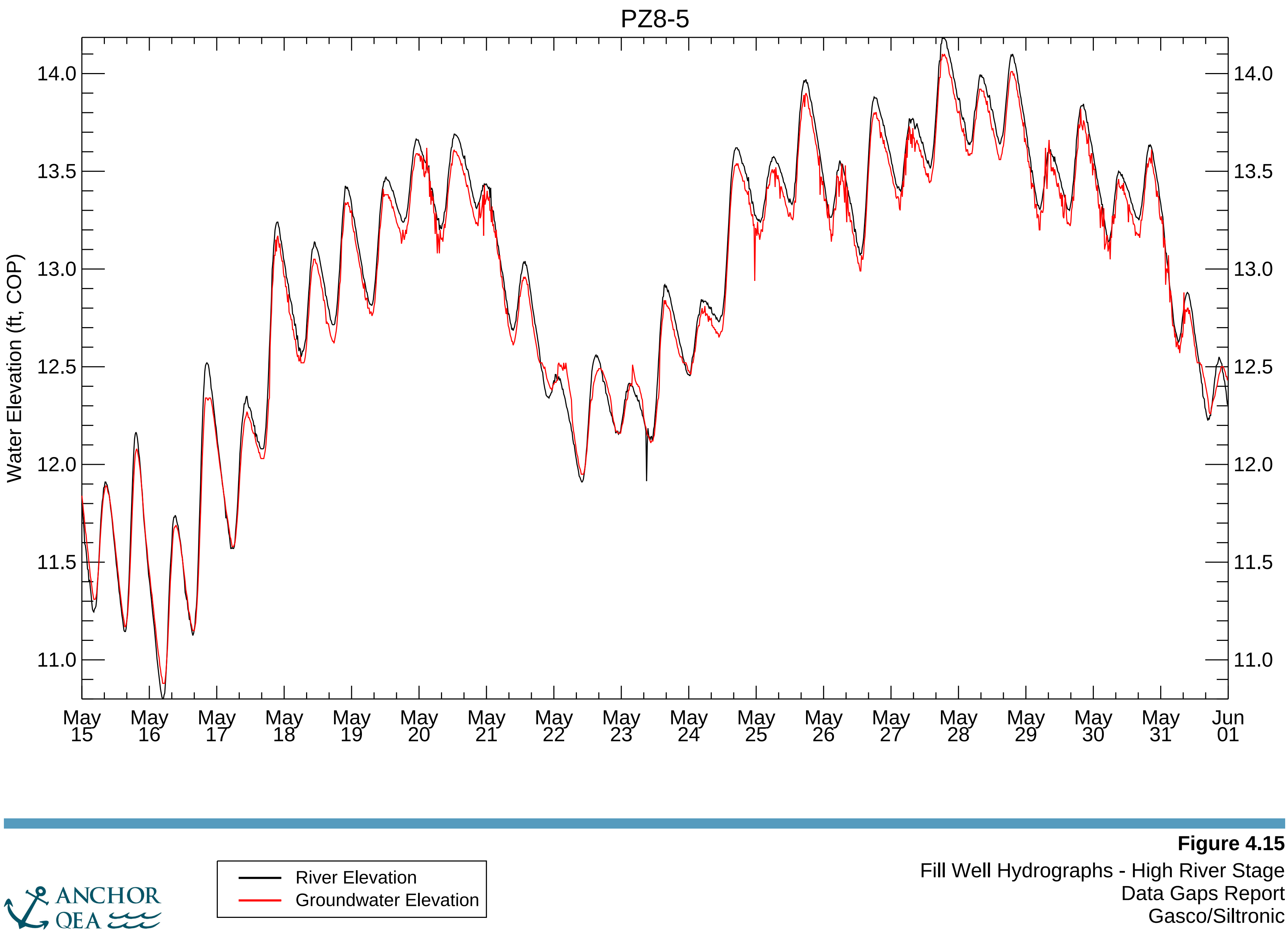

Figure 4.15

Fill Well Hydrographs - High River Stage

Data Gaps Report

Gasco/Siltronic

ANCHOR QEA

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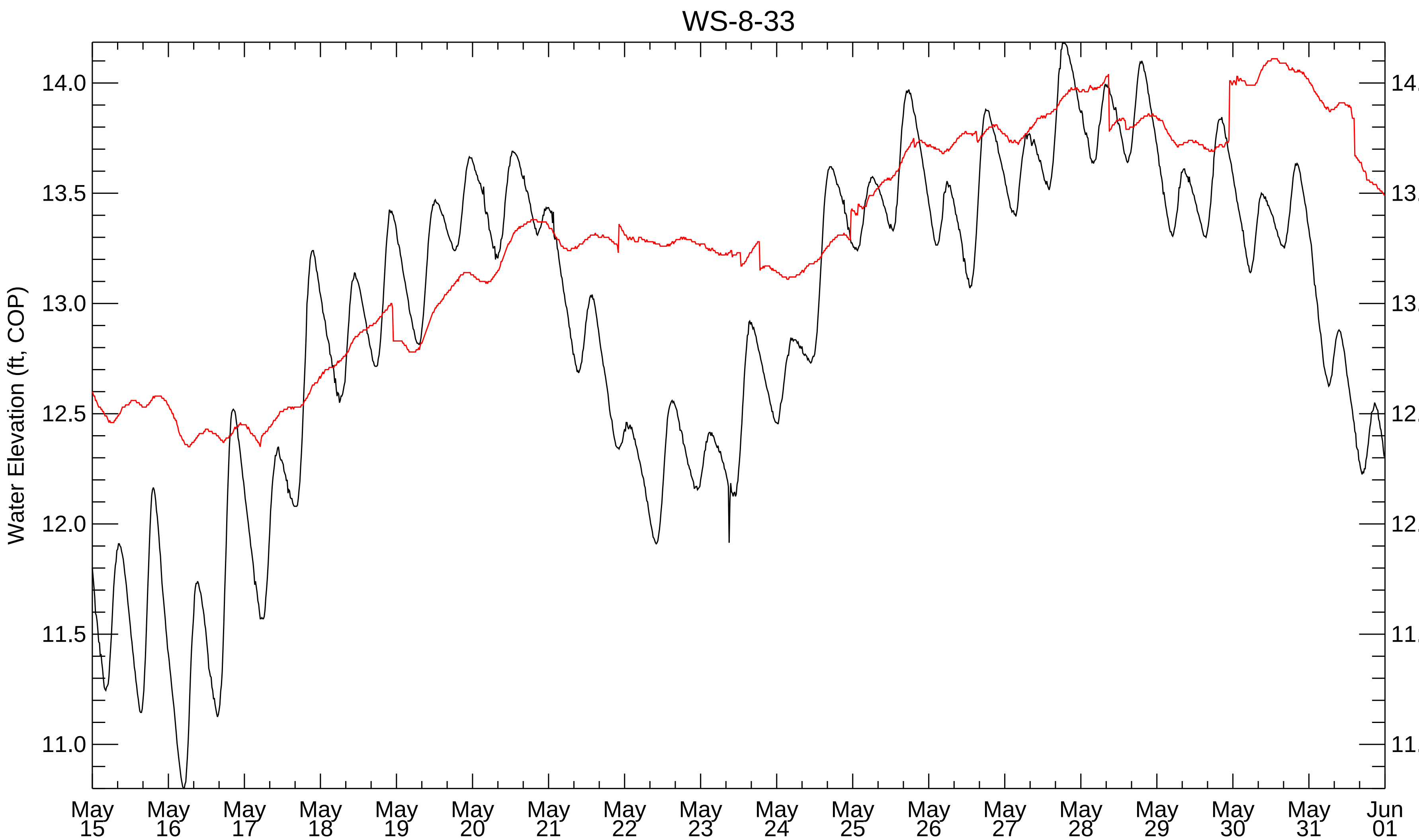

ANCHOR QEA

Figure 4.16

Fill Well Hydrographs - High River Stage
Data Gaps Report
Gasco/Siltronic

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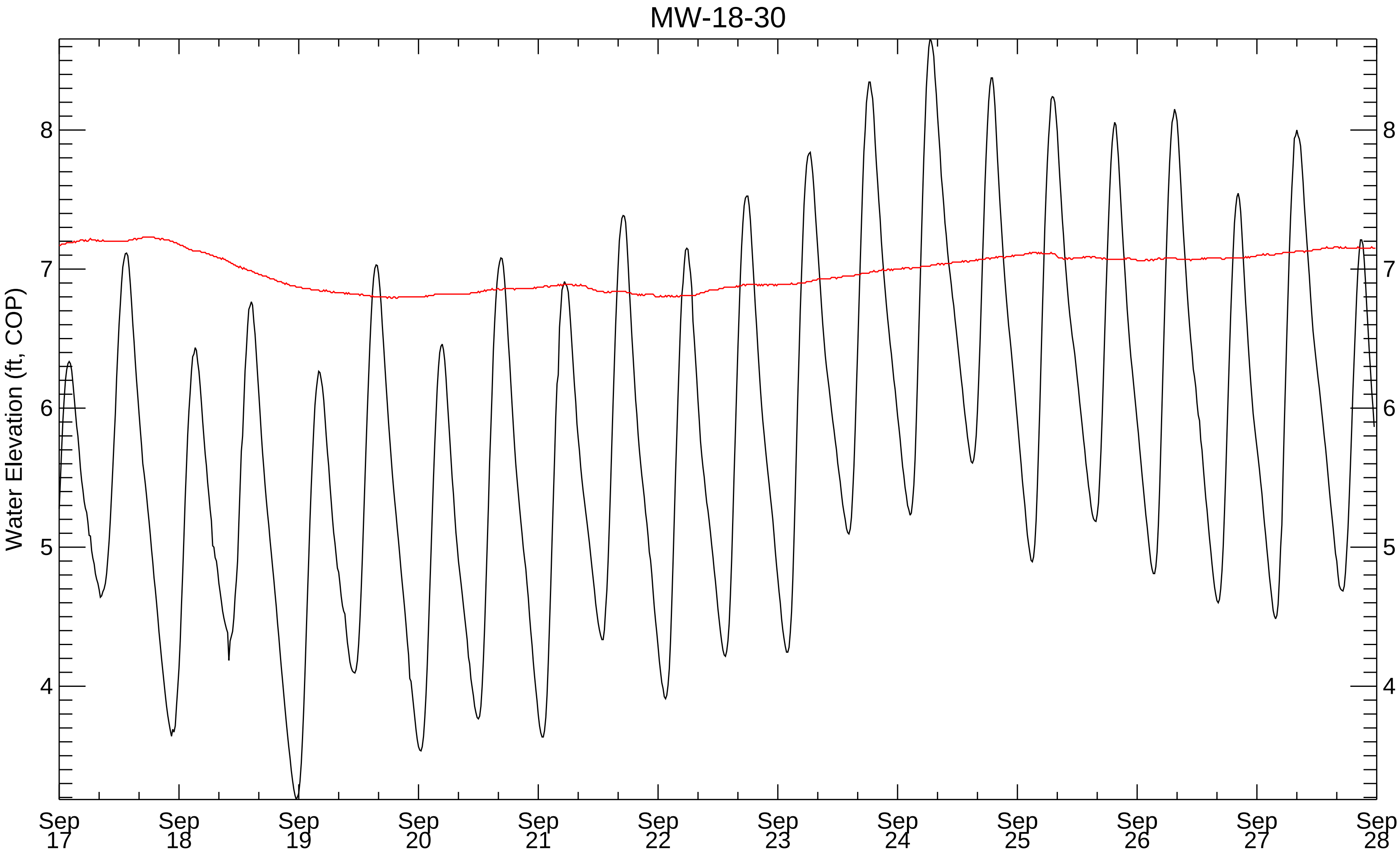

ANCHOR QEA

Figure 5.1
Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:04 2015

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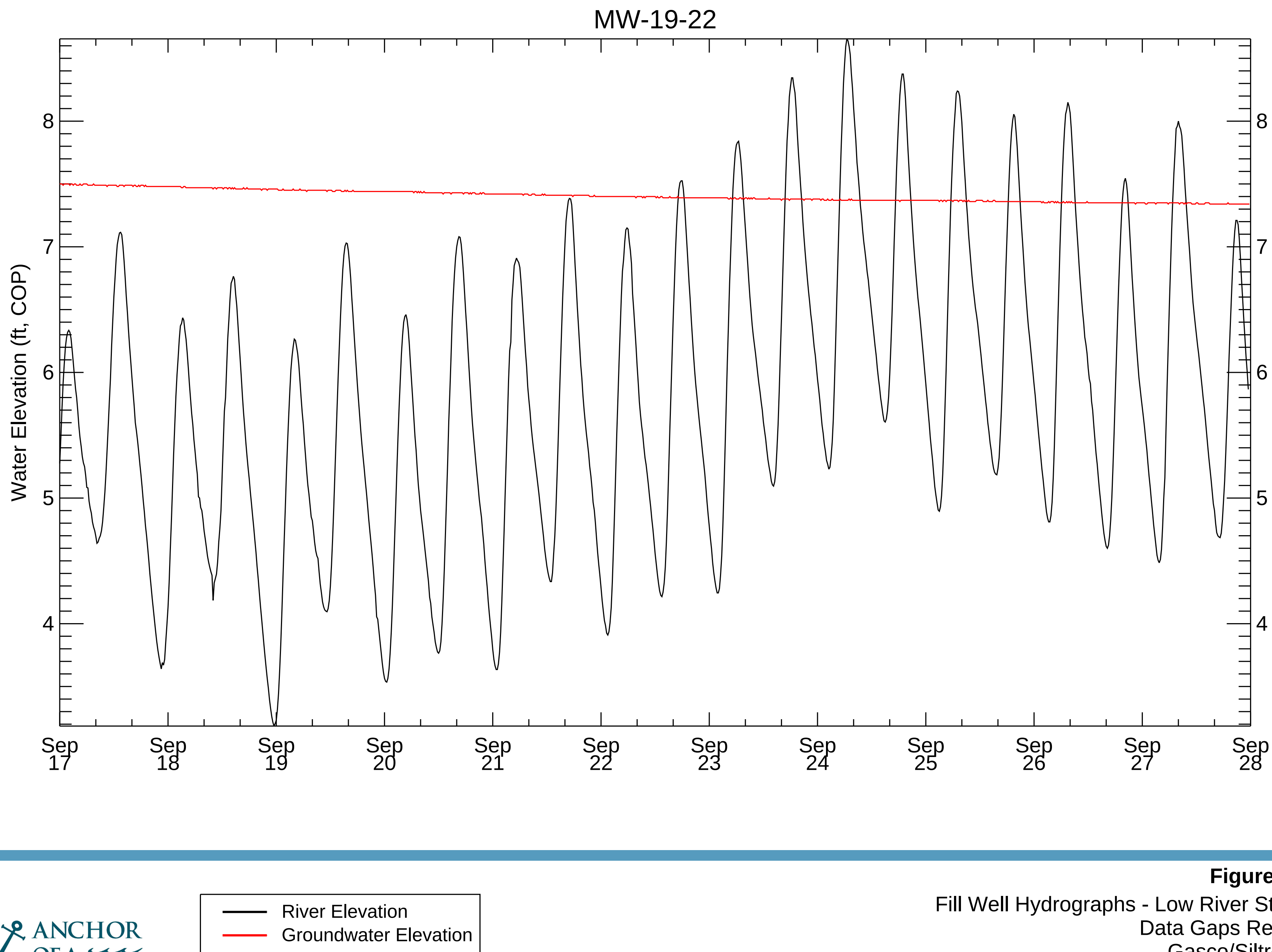

Figure 5.2

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:04 2015

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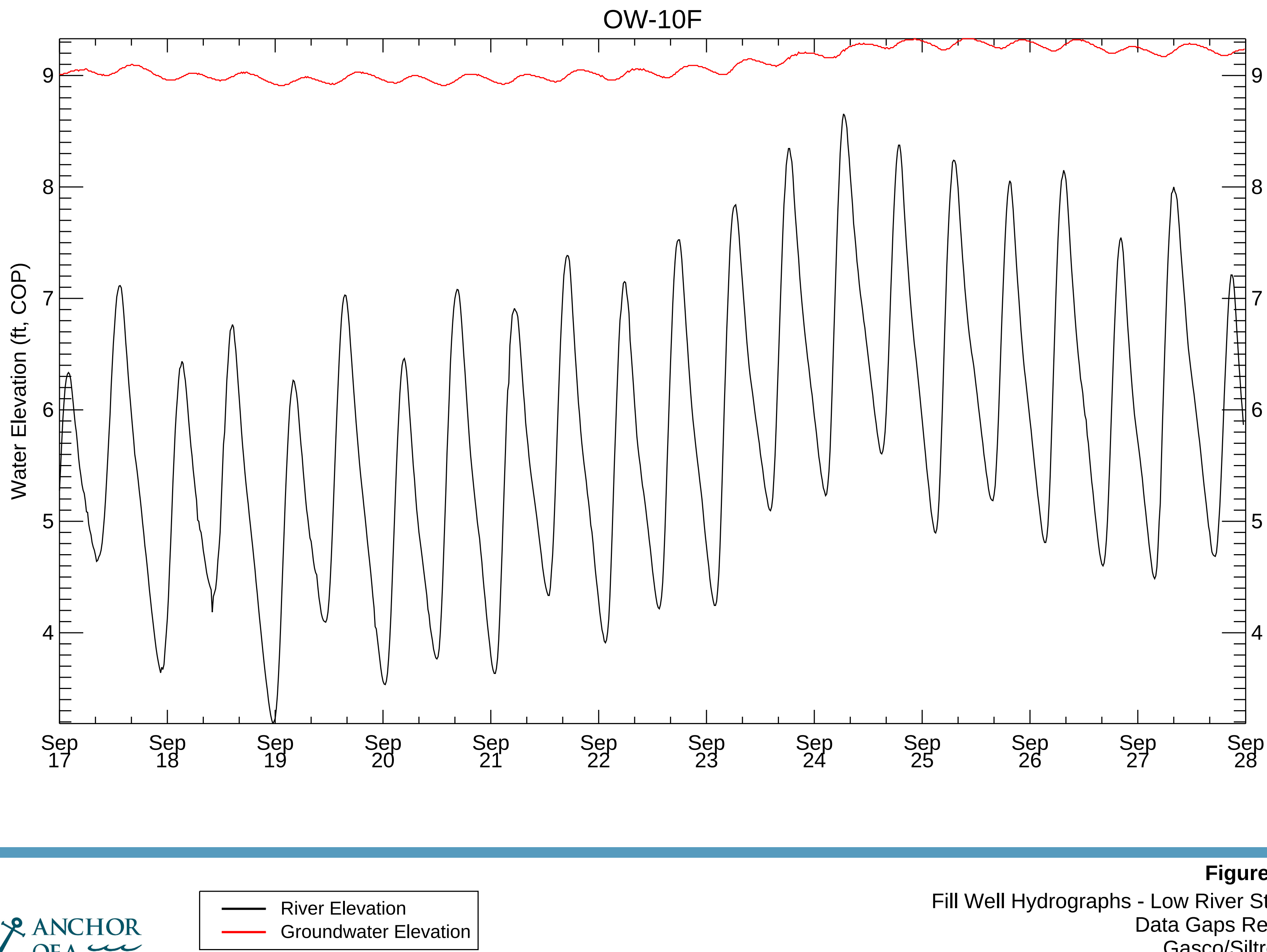

ANCHOR QEA

Figure 5.3

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:05 2015

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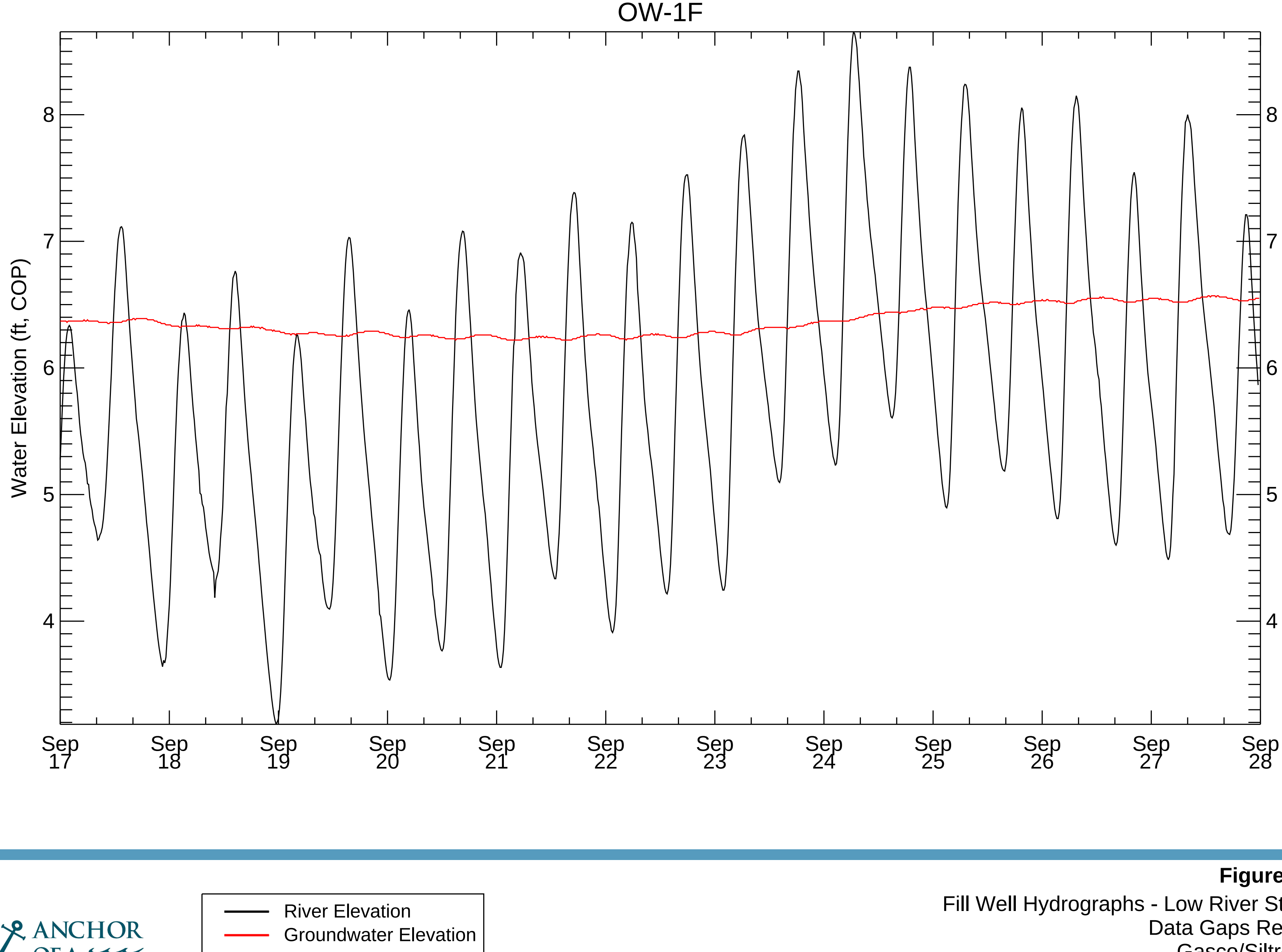

ANCHOR QEA

Figure 5.4
Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

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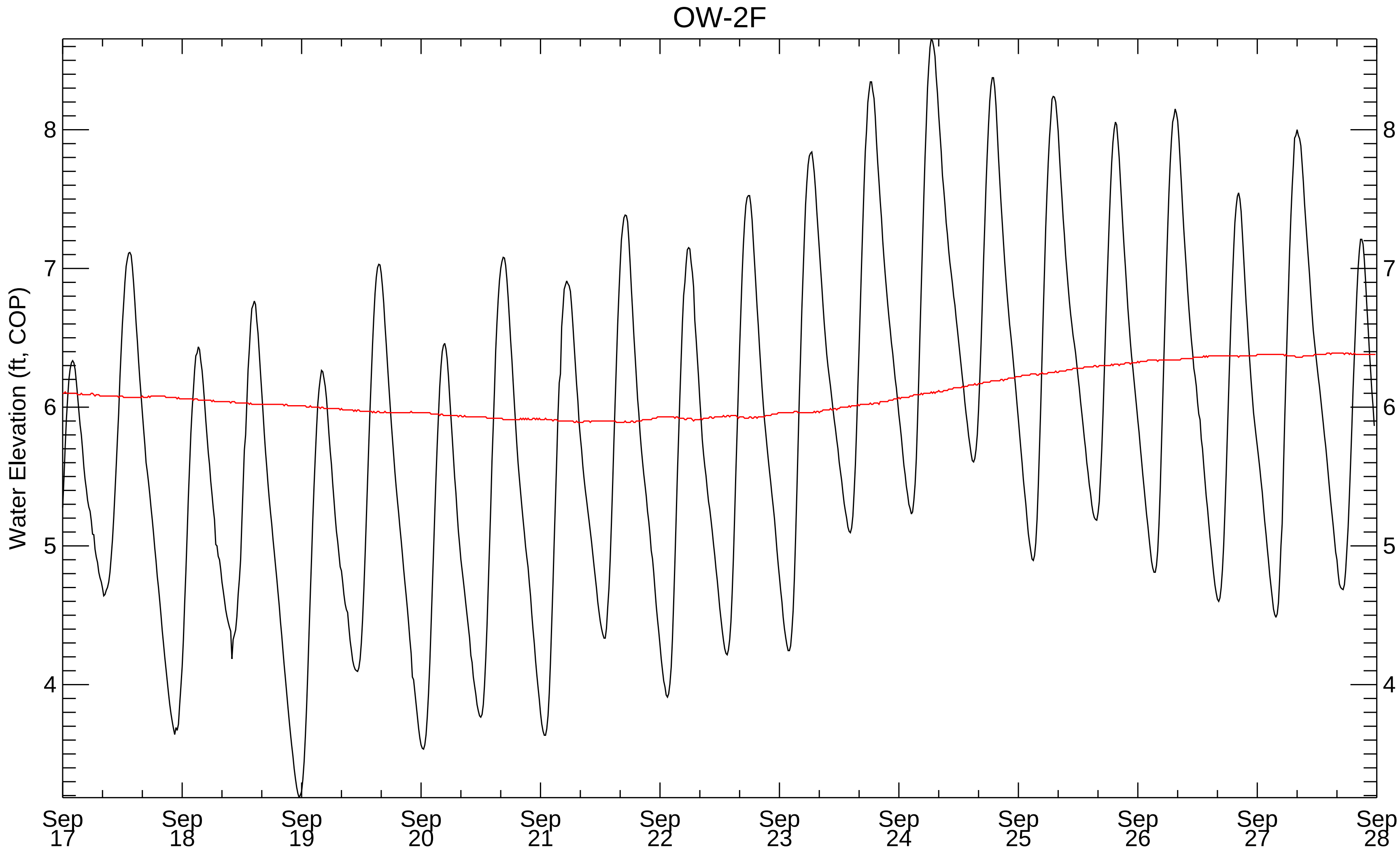

Figure 5.5

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:05 2015

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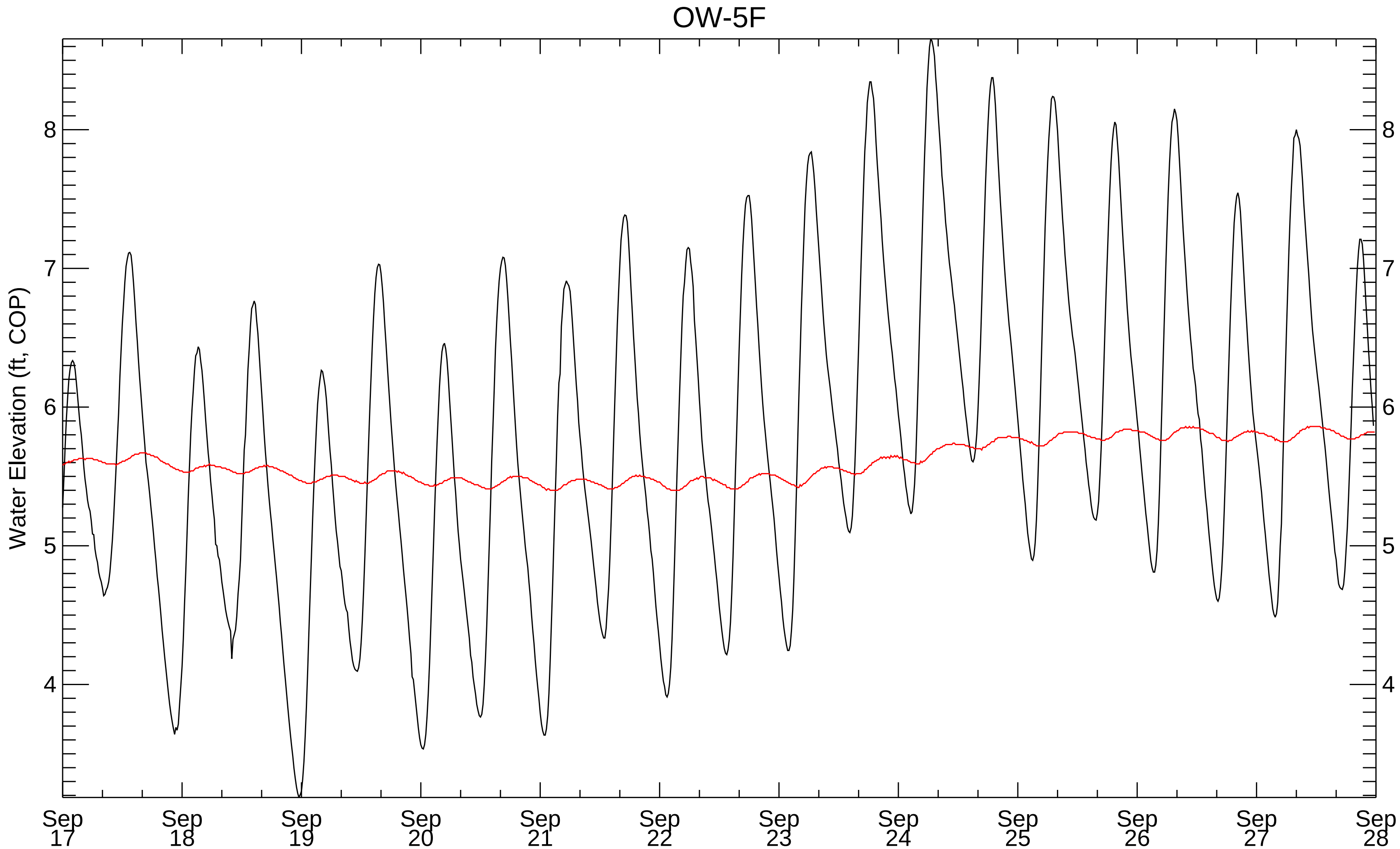

River Elevation
Groundwater Elevation

ANCHOR QEA

Figure 5.6

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

Fill

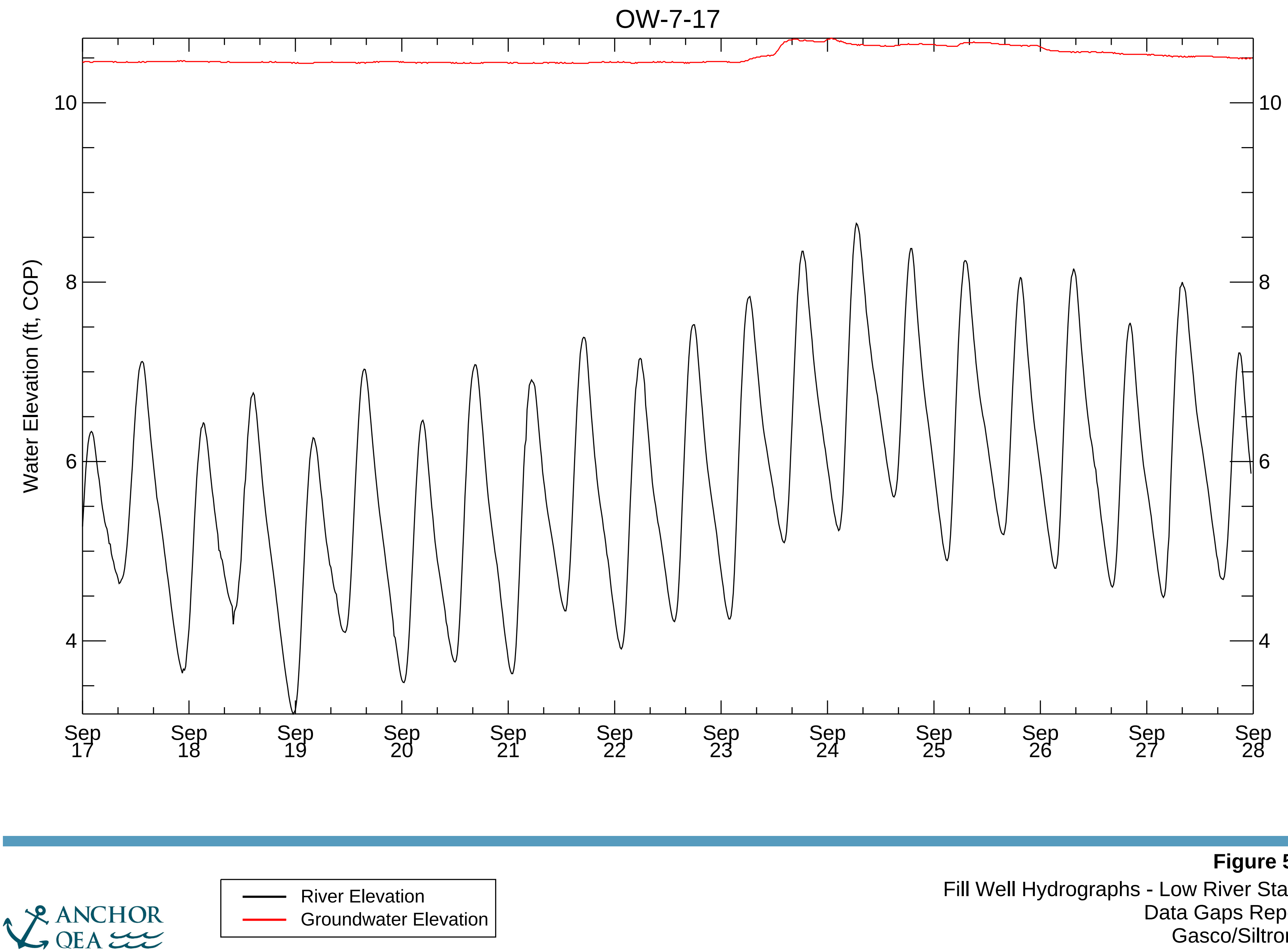

Figure 5.7

Fill Well Hydrographs - Low River Stage

Data Gaps Report

Gasco/Siltronic

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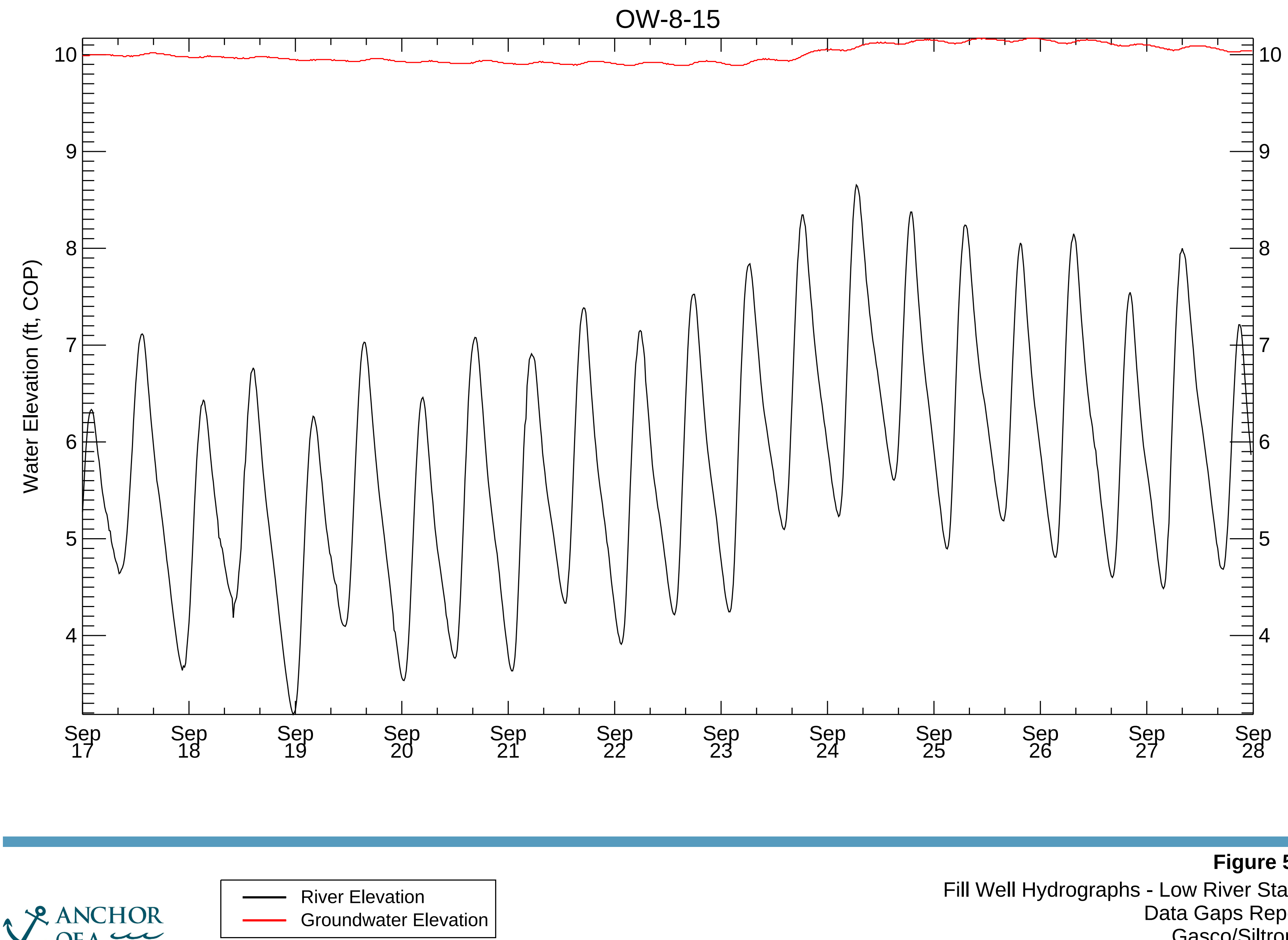


Figure 5.8

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

Fill

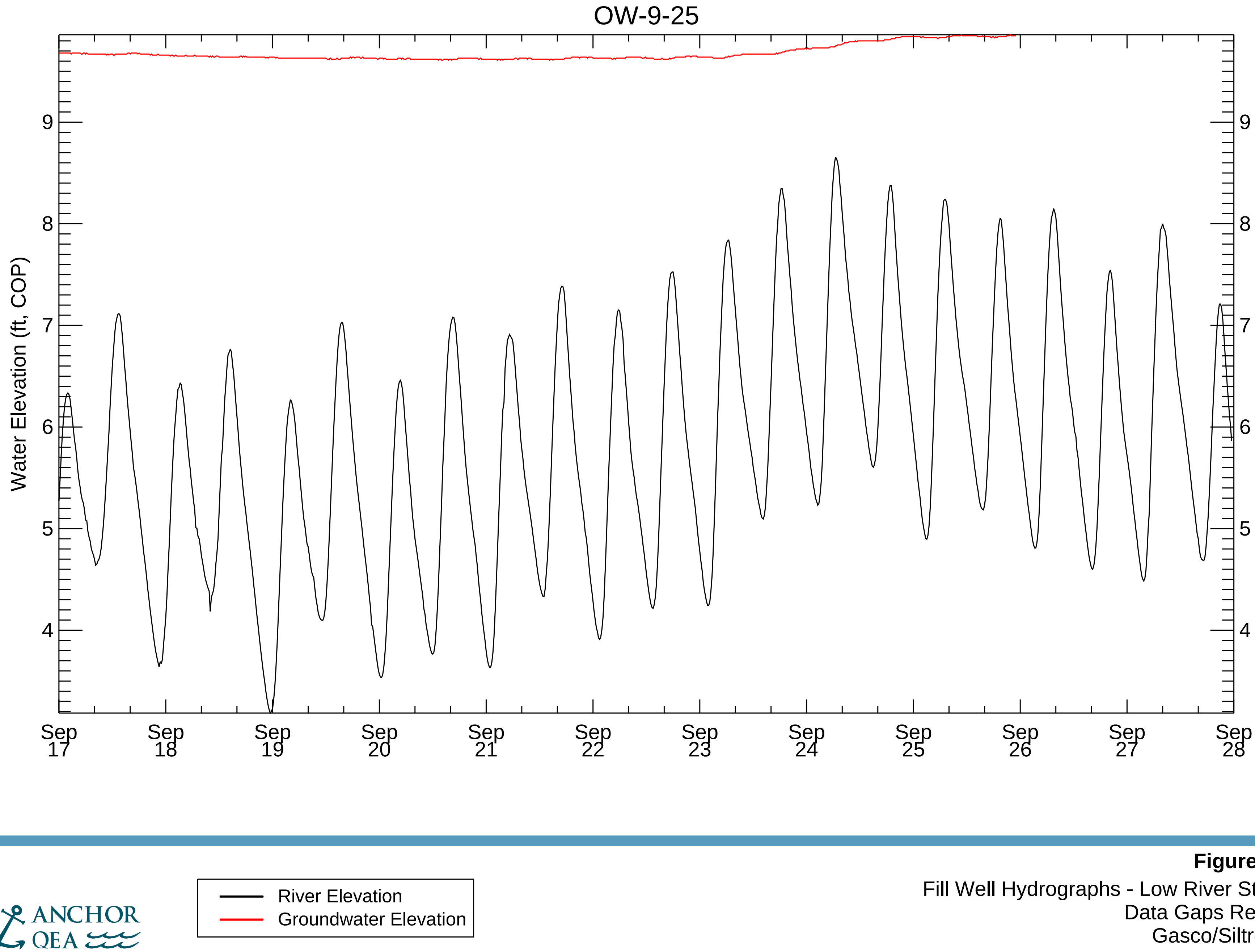
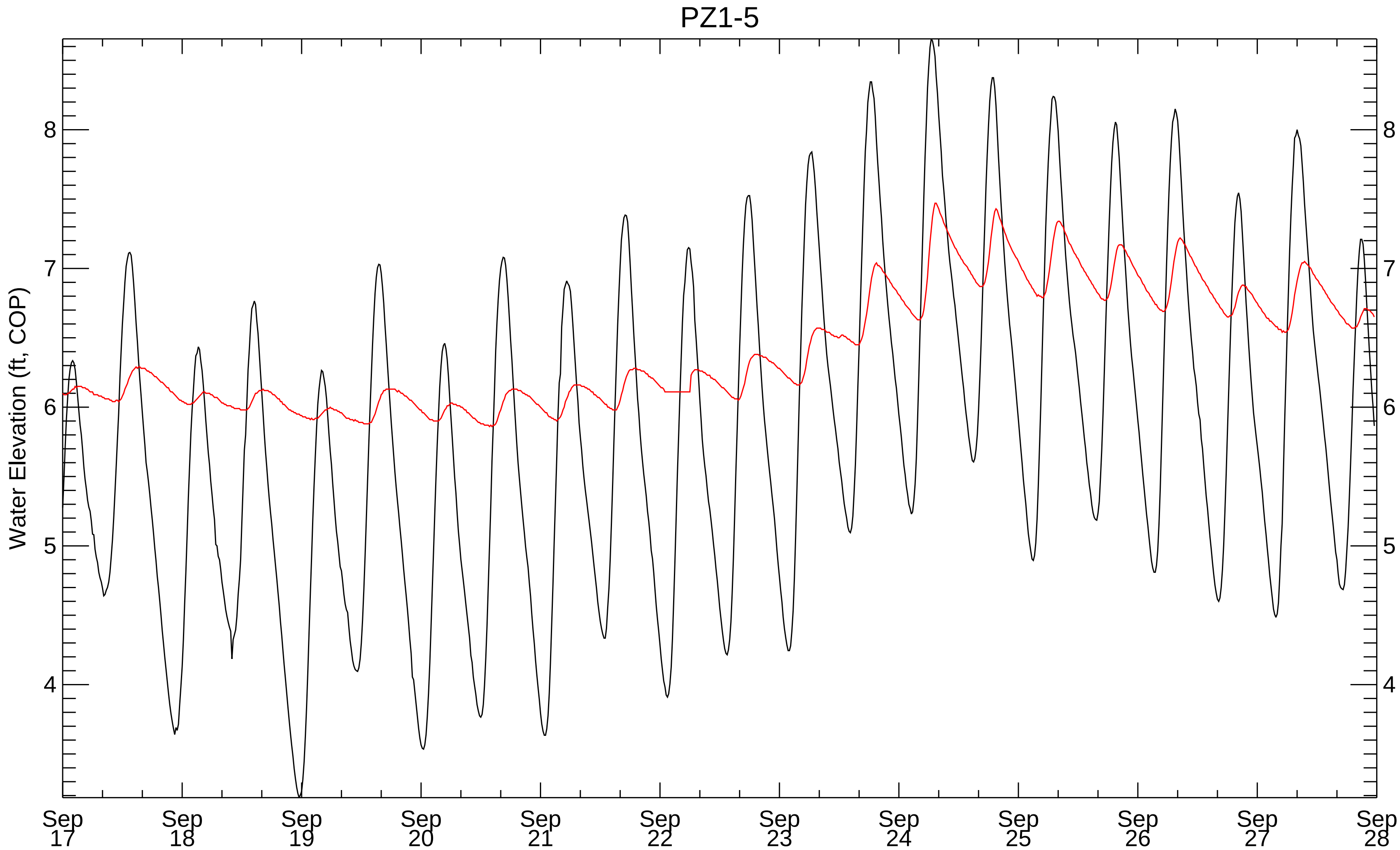


Figure 5.9

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

Fill



River Elevation
Groundwater Elevation

Figure 5.10

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

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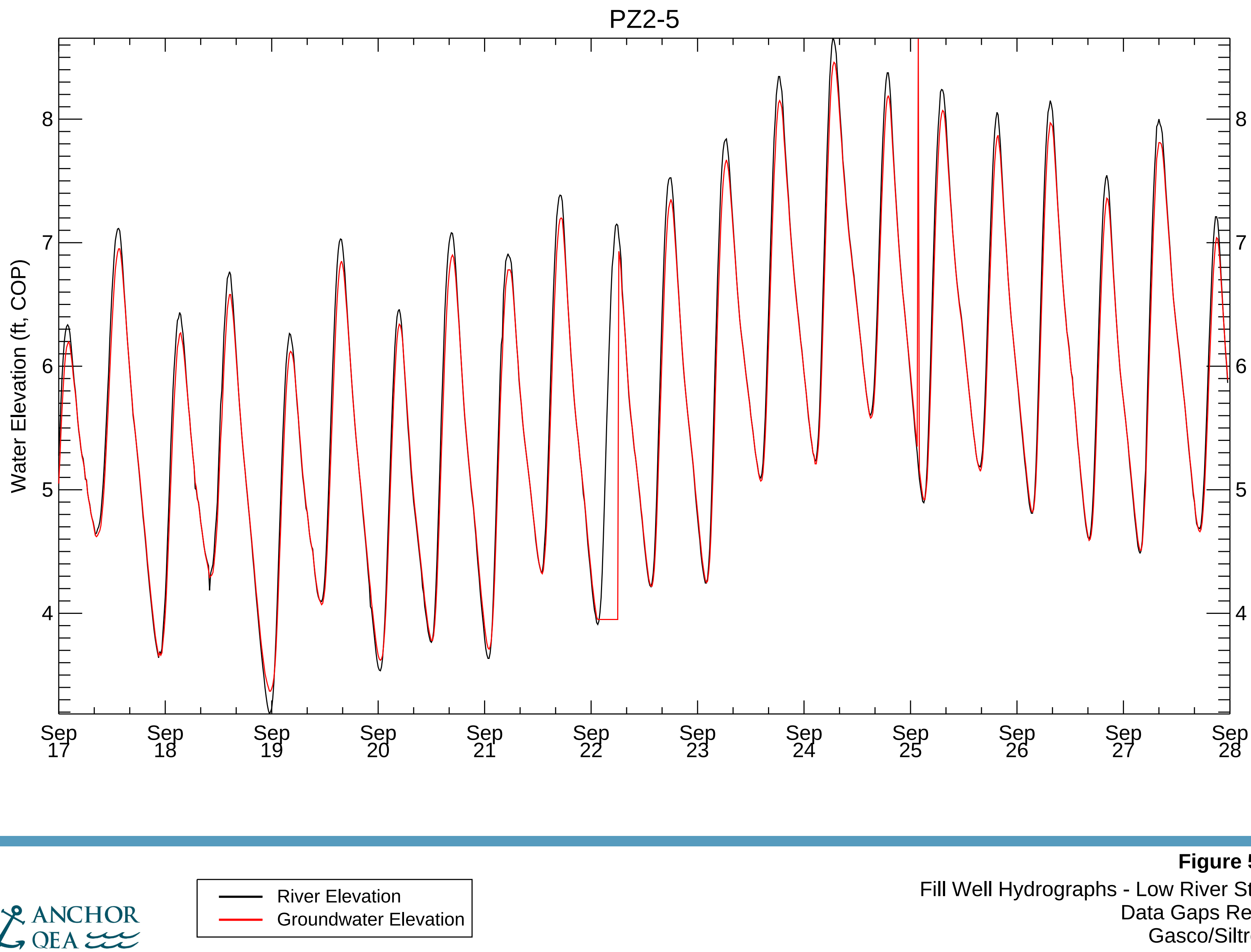

ANCHOR QEA

Figure 5.11
Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

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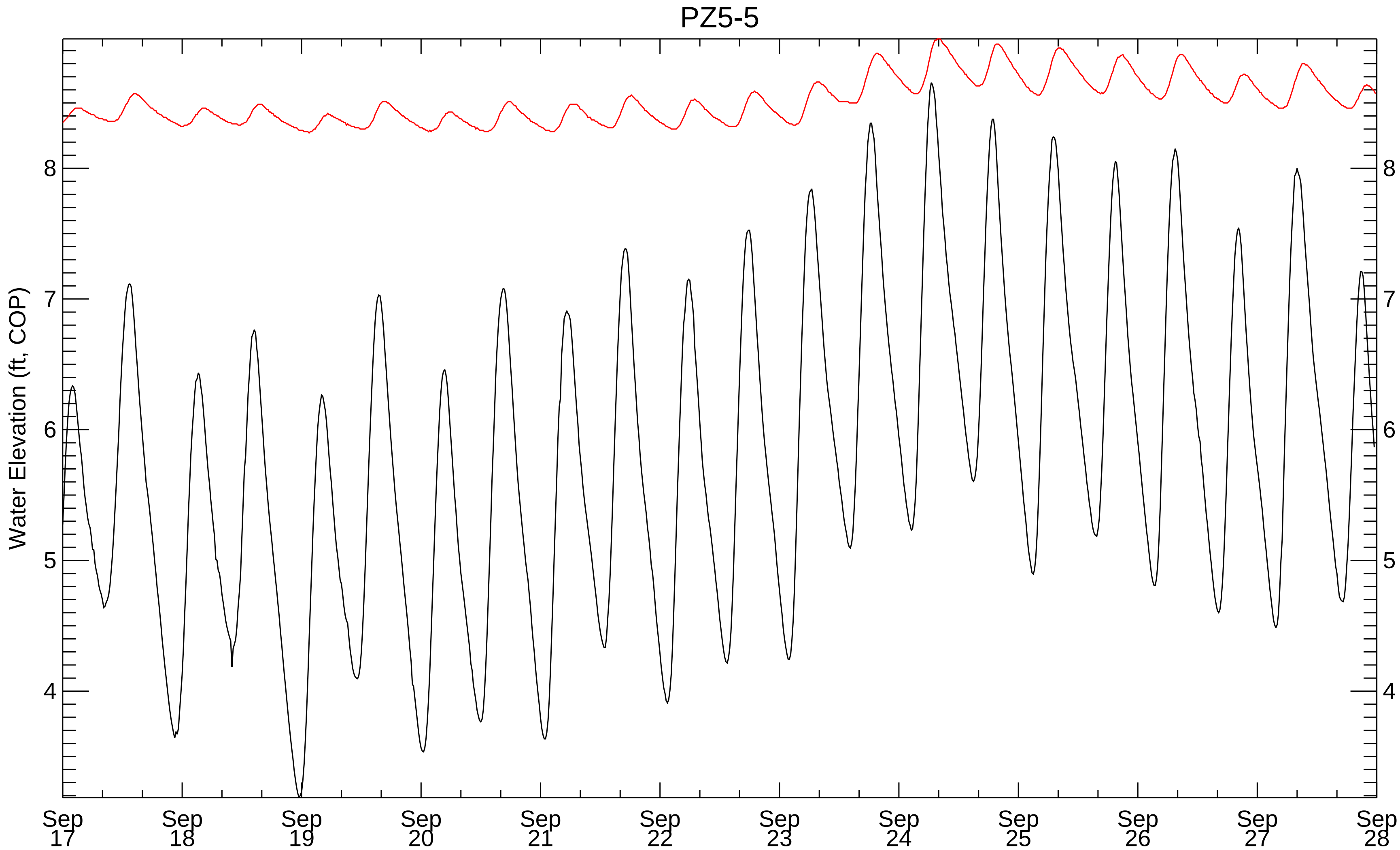

ANCHOR QEA

River Elevation
Groundwater Elevation

Figure 5.12

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:05 2015

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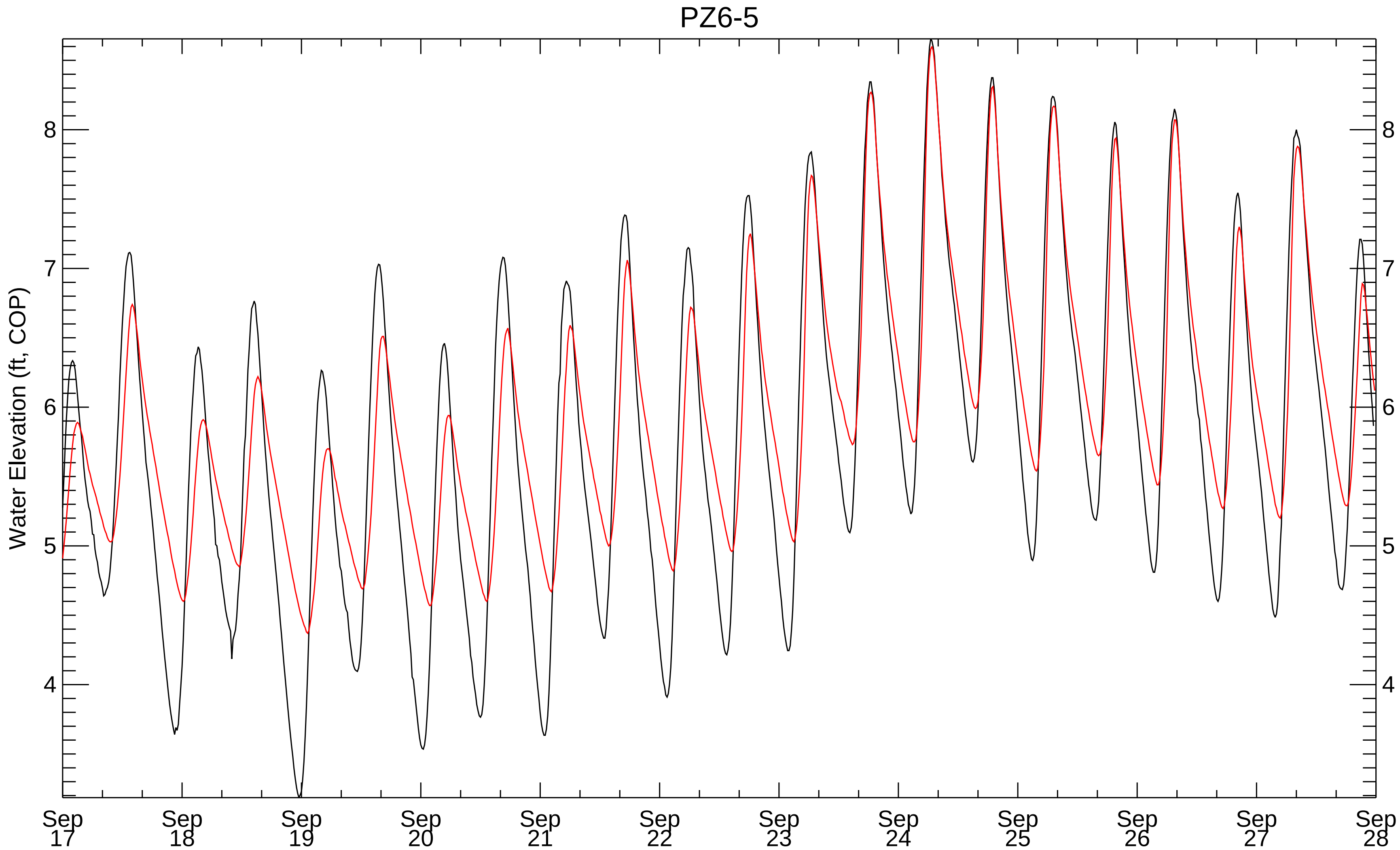

River Elevation
Groundwater Elevation

Figure 5.13

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

Fill

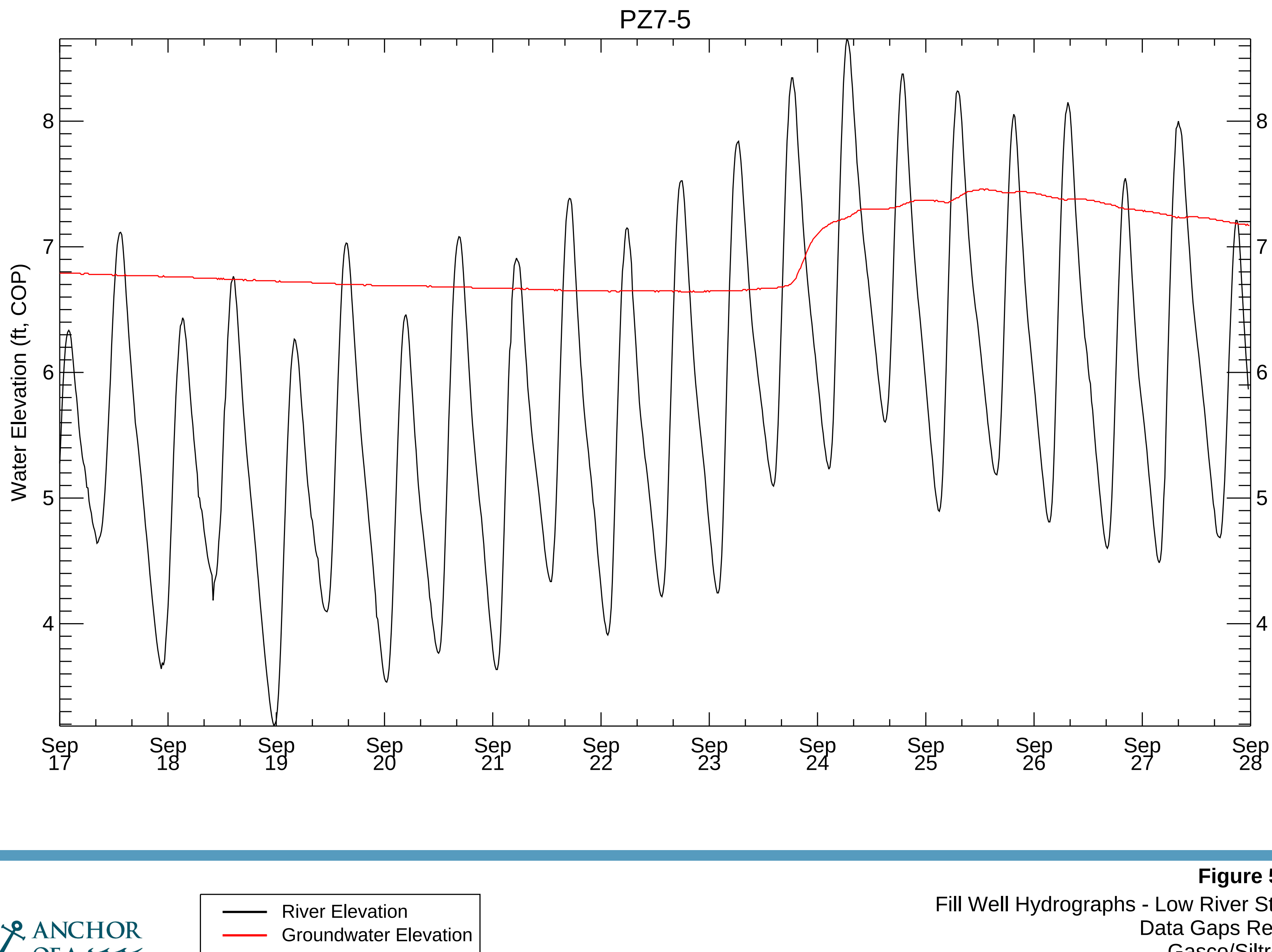

Figure 5.14

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

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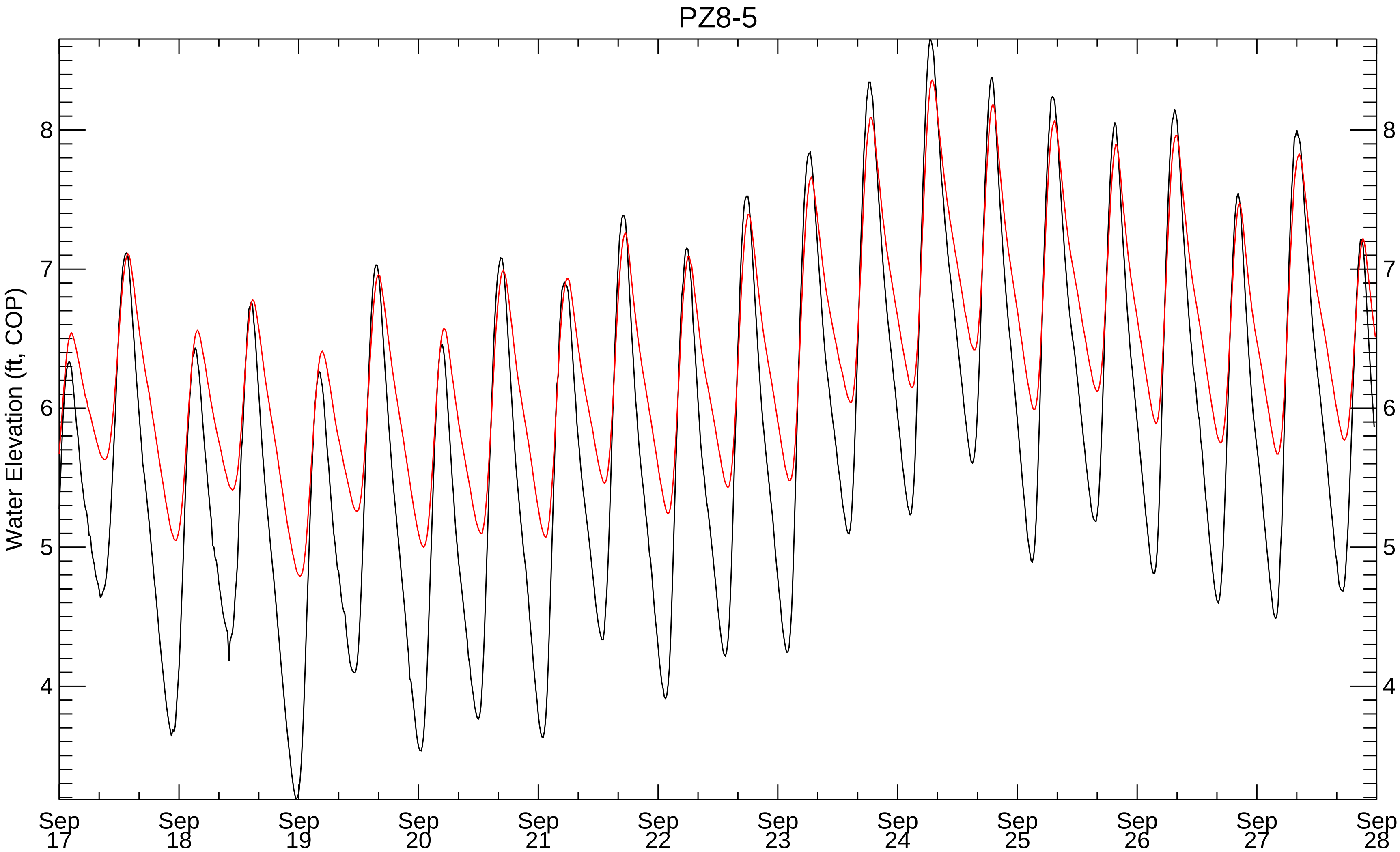

Figure 5.15

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

ANCHOR QEA

BG - C:\D_Drive\WORK\Gasco\Source_Control_Evaluation\IDL\Gasco_SC_mod_prep__plot_precip_GWelev.pro Wed Mar 18 14:31:05 2015

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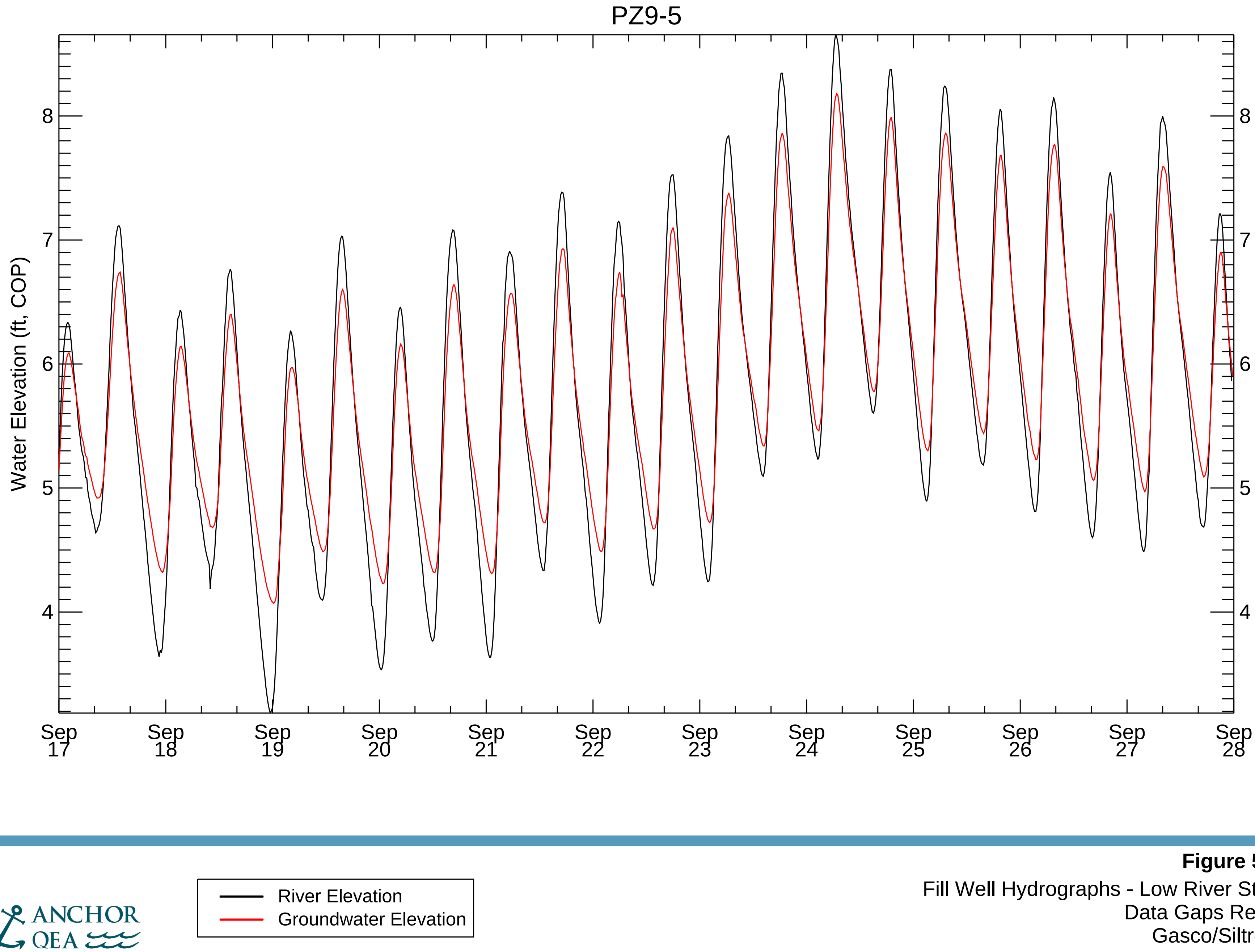

Figure 5.16

Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

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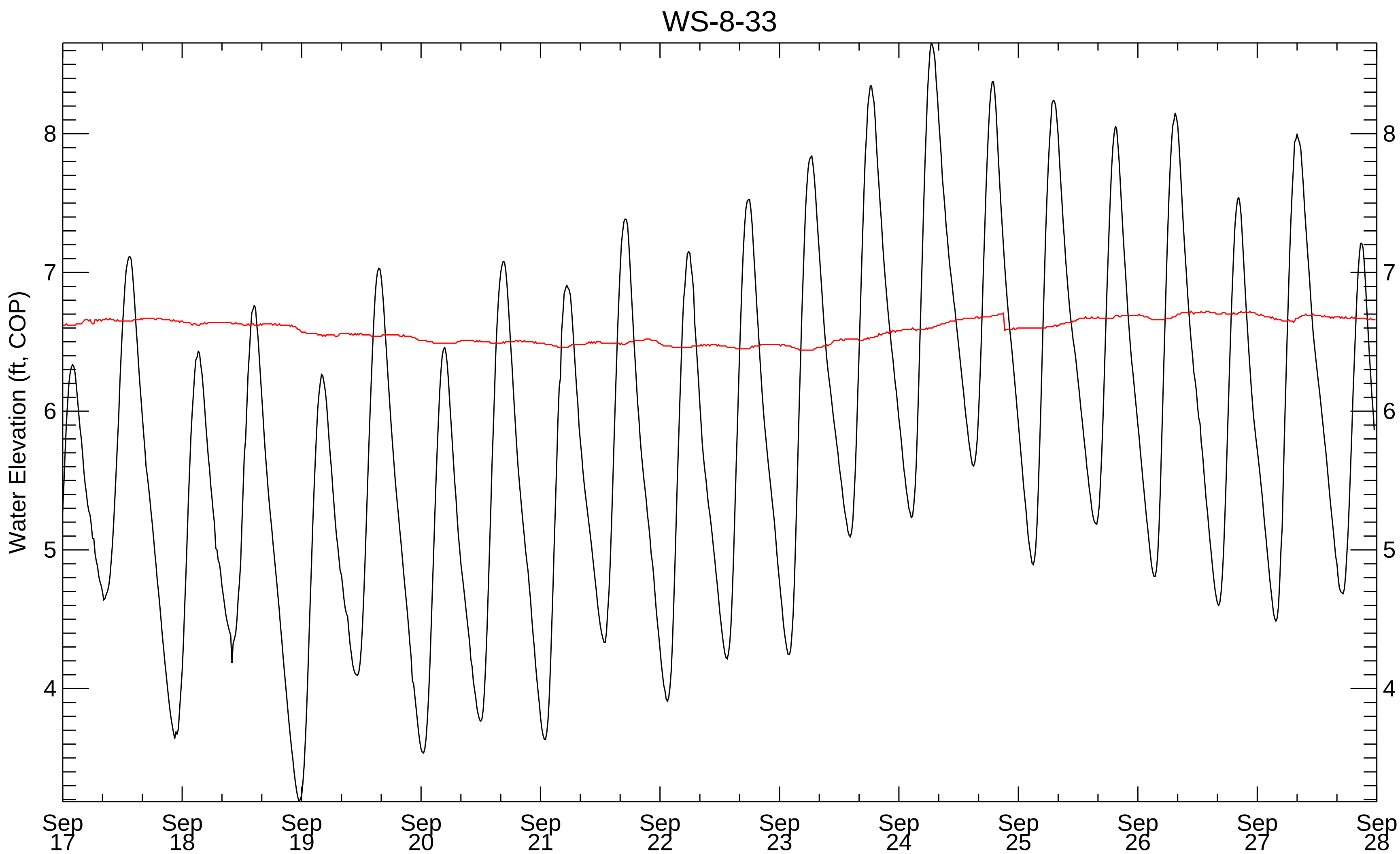

Figure 5.17
Fill Well Hydrographs - Low River Stage
Data Gaps Report
Gasco/Siltronic

ATTACHMENT A
SOIL BORING AND MONITORING WELL LOGS

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**AQ-B8**
LOCATION	**Portland, Oregon**	PAGE	**1 of 3**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**45.0 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/25/14**
GROUND SURFACE ELEVATION	**34.67 ft C.O.P.**	PERMIT/STARTCARD NO.	**NA**
TOP OF CASING ELEVATION	**NA**	WATER RESOURCES WELL ID	**NA**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET
CB	4 7 11	2.5/2.5	MC=11.2	
CB	8 12 14	2.5/2.5	MC=10.1	
CB	5 5 6	2.4/2.5	MC=9.3	5
CB	7 10 12	2.5/2.5	MC=9.4	
CB	7 14 16	5.1/5.0	MC=12.4	10
CB	3 7 9	4.4/5.0	MC=12.4	15
				20

LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
0 to 0.6 foot: SILTY GRAVELLY SAND (SM), brown, no plasticity, some angular gravel, loose, damp, rootlets. (FILL)	20	50	30
0.6 to 17.3 feet: SAND (SP), brown, fine to medium grains, loose, damp, trace gravel, fine to medium trace organic debris. (FILL)	5	95	0
@ 11.1 to 11.2 feet: black layers laminated.			
@ 11.4 to 11.5 feet: black layers laminated.			
@ 12.2 to 12.4 feet: black staining.			
@ 14.0 to 14.8 feet: silt with sand (ML), gray black, slight hydrocarbon odor.	0	25	75
@ 16.1 to 16.2 feet: oxidized iron/brick?			
@ 17.2 to 17.3 feet: silt (ML).			
17.3 to 25.0 feet: SAND (SP), black, fine to medium grains, trace gravel, loose, damp, hydrocarbon odor. (FILL)	5	95	0

REMARKS

MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

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LOG OF EXPLORATORY BORING

PROJECT NAME	NW Natural GW Source Control	BORING NO.	AQ-B8
LOCATION	Portland, Oregon	PAGE	2 of 3
DRILLED BY	Cascade Drilling, Inc., Zone S	LOGGED BY	Ben Johnson
DRILL METHOD	Rotosonic with SPT	TOTAL DEPTH	45.0 ft.
BOREHOLE DIAMETER	4" core barrel, 6" casing	DATE COMPLETED	11/25/14
GROUND SURFACE ELEVATION	34.67 ft C.O.P.	PERMIT/STARTCARD NO.	NA
TOP OF CASING ELEVATION	NA	WATER RESOURCES WELL ID	NA

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	3 7 7	4.9/5.0	MC=10.1				**17.2 to 25.0 feet: SAND (SP)**, continued. @ 19.8 feet: crushed rock. @ 21.2 to 21.8 feet: silt (ML), brown with black laminae, hydrocarbon odor, no plasticity, trace gravel, organic debris. (FILL)	5	10	85
CB	2 4 3	2.3/5.0	MC=8.8	25			**25.0 to 35.0 feet: SILTY SAND (SM)**, black, fine to medium sand, silt blebs/chunks, loose, damp, hydrocarbon odor, sheen. (FILL)	5	70	25
CB	4 2 3	1.4/5.0	MC=29.8	30			@ 33.5 to 35.0 feet: silt (ML), gray, trace gravel, hydrocarbon odor, wood debris, sheen.			
CB	0 1 1	4.6/5.0	MC=39.0 LL=37 PL=27 PI=10	35			**35.0 to 36.8 feet: SILT WITH SAND (ML)**, gray with orange/brown spots, low plasticity, fine sand, soft, damp. (ALLUVIUM)	0	20	80
							36.8 to 38.5 feet: SANDY SILT (ML), gray, fine to medium sand, some brown mottling, firm, no plasticity, occasional sand vein. (ALLUVIUM)	0	30	70
				40			**38.5 to 40.5 feet: SILTY SAND (SM)**, gray, fine sand, firm, damp, trace organic debris. (ALLUVIUM)	0	75	25

REMARKS
MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	NW Natural GW Source Control	BORING NO.	AQ-B8
LOCATION	Portland, Oregon	PAGE	3 of 3
DRILLED BY	Cascade Drilling, Inc., Zone S	LOGGED BY	Ben Johnson
DRILL METHOD	Rotosonic with SPT	TOTAL DEPTH	45.0 ft.
BOREHOLE DIAMETER	4" core barrel, 6" casing	DATE COMPLETED	11/25/14
GROUND SURFACE ELEVATION	34.67 ft C.O.P.	PERMIT/STARTCARD NO.	NA
TOP OF CASING ELEVATION	NA	WATER RESOURCES WELL ID	NA

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	0 1 4	4.3/5.0	MC=37.1 LL=36 PL=30 PI=6				**38.5 to 40.5 feet: SILTY SAND (SM)**, continued.			
							40.5 to 43.7 feet: SILT WITH SAND (ML), gray, fine sand, no plasticity, firm, damp, trace organic debris. (ALLUVIUM) @ 41.5 to 41.9 feet: gray sand content up.	0	20	80
							43.7 to 45.0 feet: SILTY SAND (SM), gray, fine sand, loose, damp. (ALLUVIUM)	0	75	25
				45			Total depth: 45.0 feet.			
				50						
				55						
				60						

REMARKS

MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-39F**
LOCATION	**Portland, Oregon**	PAGE	**1 of 2**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**26.5 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/17/14**
GROUND SURFACE ELEVATION	**31.09 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025003**
TOP OF CASING ELEVATION	**34.25 ft C.O.P.**	WATER RESOURCES WELL ID	**L115796**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	2 3 3	3.0/2.5	MC=17.5		**0 to 0.5 foot: GRAVELLY SILT (ML)**, no plasticity, brown silt, gray gravel, soft, damp, 3/4" minus, road gravel.	50	0	50
					0.5 to 2.5 feet: SILT WITH GRAVEL (ML), brown, small gravels, no plasticity, damp, soft, mixed gravels, angular rounded, some brick, roots. (FILL) @ 2.3 to 2.5 feet: dry crushed rock.	40	2	58
CB	5 35 7	1.0/2.5	MC=10.5		**2.5 to 5.0 feet: GRAVELLY SAND (SW)**, brown sand, gray gravel, loose, dry, concrete pieces. (FILL) @ 4.2 to 5.0 feet: concrete.	40	55	5
CB	3 3 4	2.0/2.5	MC=17.1	5	**5.0 to 12.9 feet: GRAVELLY SILT (ML)**, brown silt, gray gravel, firm, damp, gravel rounded and angular, trace brick. (FILL) @ 5.3 to 5.7 feet: more gravel. @ 6.9 to 7.5 feet: some black mottling, firm silt.	40	2	58
CB	17 7 6	1.8/2.5	MC=16.1		@ 7.5 to 8.5 feet: crushed concrete.			
CB	2 3 8	3.8/5.0	MC=18.8	10	@ 9.7 to 10.0 feet: some red in silt matrix, large cobble.			
					12.9 to 14.5 feet: WOOD PULP. (FILL)			
					14.5 to 15.0 feet: LAMPBLACK, trace gravel, some wood pulp, hydrocarbon odor. (FILL)			
CB	3 3 4	4.8/5.0	MC=47.7	15	**15.0 to 15.7 feet: WOOD PULP**, lampblack, some silt.			
					15.7 to 16.0 feet: BRICK.			
					16.0 to 16.6 feet: SAND (SP), light brown, fine grained, soft, damp, some black veins. (FILL)	0	95	5
					16.6 to 20.0 feet: SILT (ML), black and gray swirls getting lighter with depth, soft, no plasticity, some rootlets, trace hydrocarbon odor, no sheen, damp. (ALLUVIUM)	0	14	86
				20				

REMARKS
MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-39F**
LOCATION	**Portland, Oregon**	PAGE	**2 of 2**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**26.5 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/17/14**
GROUND SURFACE ELEVATION	**31.09 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025003**
TOP OF CASING ELEVATION	**34.25 ft C.O.P.**	WATER RESOURCES WELL ID	**L115796**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	1 2 2	5.0/5.0	MC=38.8 LL=38 PL=32 PI=6				**20.0 to 26.5 feet: SILT WITH SAND (ML)**, gray, fine sand, soft, damp, nonplasticity. (ALLUVIUM) @ 20.0 to 21.3 feet: black veins. @ 21.3 to 21.5 feet: some gravel and organic debris.	0	20	80
CB	0 0 4	1.5/5.0		25						
				30 35 40			Total depth: 26.5 feet. **WELL COMPLETION DETAILS** 0 to 11.8 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC blank riser pipe. 11.8 to 16.85 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC well screen with 0.020-inch machined slots. 16.85 to 17.25 feet: Sump. 0 to 2.5 feet: Concrete. 2.5 to 7.0 feet: Granular bentonite. 7.0 to 9.3 feet: Bentonite chips. 9.3 to 17.25 feet: 10-20 Colorado Silica Sand. 17.25 to 26.5 feet: Bentonite chips.			

REMARKS

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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	NW Natural GW Source Control	BORING NO.	MW-40F
LOCATION	Portland, Oregon	PAGE	1 of 3
DRILLED BY	Cascade Drilling, Inc., Zone S	LOGGED BY	Ben Johnson
DRILL METHOD	Rotosonic with SPT	TOTAL DEPTH	36.5 ft.
BOREHOLE DIAMETER	4" core barrel, 6" casing	DATE COMPLETED	11/18/14
GROUND SURFACE ELEVATION	35.98 ft C.O.P.	PERMIT/STARTCARD NO.	1025004
TOP OF CASING ELEVATION	39.25 ft C.O.P.	WATER RESOURCES WELL ID	L115797

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	2 3 4	2.0/2.5	MC=11.8		**0 to 5.0 feet: SILT WITH GRAVEL (ML)**, dark brown silt, gray/light gravels, loose, damp, no plasticity, some rounded gravel, other concrete. (FILL)	20	2	78
CB	16 5 3	2.3/2.5	MC=16.5		@ 2.5 to 5.0 feet: sand content up to ~10 percent. @ 4.2 to 4.4 feet: wire.			
CB	3 3 2	2.5/2.5	MC=17.8 LL=33 PL=20 PI=13	5	**5.0 to 10.0 feet: SILT WITH GRAVEL (ML)**, dark brown silt, some gray gravel, soft, damp, medium plasticity, rounded gravel, trace wood. (FILL)	15	15	70
CB	0 1 2	2.5/2.5			@ 7.2 to 7.4 feet: asphalt, black, hard, granular texture. @ 7.5 feet: sand content down <5 percent, gravel down ~10 percent, rootlets. @ 7.8 to 8.1 feet: basalt ballast rock, iron staining in silt.			
CB	0 1 5	3.5/5.0	MC=25.4	10	**10.0 to 13.4 feet: SILTY SAND (SM)**, dark gray to black, gray/light brown sand, loose, damp, hydrocarbon odor, poorly graded, black staining. @ 11.4 feet: wood pulp.	5	85	10
					13.4 to 15.0 feet: LAMPBLACK/CARBON PITCH, black, fine grained, light weight/fluffy, hydrocarbon odor.			
CB	8 6 10	4.2/5.0	MC=18.7	15	**15.0 to 16.8 feet: SILT (ML)** with potential lampblack in matrix, black staining, stiff, damp, black, trace organic matter, twigs, hydrocarbon odor.	0	2	98
					16.8 to 22.1 feet: SAND (SP), black staining, black, loose, poorly graded, no plasticity, damp, hydrocarbon odor, silt nodules. (FILL)			
				20				

REMARKS
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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-40F**
LOCATION	**Portland, Oregon**	PAGE	**2 of 3**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**36.5 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/18/14**
GROUND SURFACE ELEVATION	**35.98 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025004**
TOP OF CASING ELEVATION	**39.25 ft C.O.P.**	WATER RESOURCES WELL ID	**L115797**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	7 10 10	4.5/5.0	MC=22.9				**16.8 to 22.1 feet: SAND (SP)**, continued. @ 20.0 to 22.1 feet: less silt. @ 21.8 to 22.1 feet: silt lense.			
							22.1 to 26.2 feet: SAND (SP), dark gray, fine to medium grains, variegated (white, clear, red) grains, loose, damp, slight hydrocarbon odor, no sheen. (FILL)	0	95	5
CB	1 3 4	6.0/5.0	MC=44.3	25						
							26.2 to 36.5 feet: SILT (ML), greenish gray, some brown mottling, high plasticity, soft, damp, some organic debris and coarse grains. (ALLUVIUM) @ 26.2 to 26.5 feet: silt in split spoon. @ 27.3 to 28.1 feet: black particles in matrix. @ 28.1 to 31.1 feet: more brown mottling and organic debris, no coarse grains.	0	2	98
CB	2 3 2	5.4/5.0	MC=39.6	30			@ 31.1 to 35.0 feet: sand content up, silt with sand (MH), no brown mottling.	0	10	90
CB	2 2 4	6.0/5.0		35						
							Total depth: 26.5 feet. See Page 3 for Well Completion Details.			
				40						

REMARKS

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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-40F**
LOCATION	**Portland, Oregon**	PAGE	**3 of 3**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**36.5 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/18/14**
GROUND SURFACE ELEVATION	**35.98 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025004**
TOP OF CASING ELEVATION	**39.25 ft C.O.P.**	WATER RESOURCES WELL ID	**L115797**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
				45						
				50						
				55						
				60						

WELL COMPLETION DETAILS

0 to 21.6 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC blank riser pipe.
21.6 to 26.65 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC well screen with 0.020-inch machined slots.
26.65 to 27.05 feet: Sump.

0 to 3.0 feet: Concrete.
3.0 to 17.0 feet: Granular bentonite.
17.0 to 19.4 feet: Bentonite chips.
19.4 to 27.0 feet: 10-20 Colorado Silica Sand.
27.0 to 36.5 feet: Bentonite chips.

REMARKS

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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-41U**
LOCATION	**Portland, Oregon**	PAGE	**1 of 2**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**30.0 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/19/14**
GROUND SURFACE ELEVATION	**37.55 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025005**
TOP OF CASING ELEVATION	**40.69 ft C.O.P.**	WATER RESOURCES WELL ID	**L115798**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET
CB	3 3 21	2.5/2.5	MC=19.9	0
CB	2 3 3	2.2/2.5	MC=11.6	2.5
CB	2 1 1	2.5/2.5	MC=27.4	5
CB	2 4 5	2.3/2.5	MC=29.2	7.5
CB	2 2 4	4.9/5.0	MC=33.7	10
CB	1 1 1	5.0/5.0	MC=35.7	15

LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
0 to 0.6 foot: SILT WITH GRAVEL (ML), brown, fine angular gravels, no plasticity, road material?, soft, damp, no odor. (FILL)	10	5	85
0.6 to 2.0 feet: SANDY SILT (ML), brown, fine to medium sand, trace gravel, no plasticity, soft, damp. (FILL)	5	25	65
2.0 to 5.7 feet: SAND (SP), brown and white, fine to medium grains, loose, damp, no anthropogenic material. (FILL) @ 4.6 to 4.8 feet: some black fine gravels.	0	5	95
5.7 to 21.5 feet: SILT (ML), brown, orange mottling, iron?, no plasticity, soft, damp, some organic debris and rootlets. (ALLUVIUM) @ 7.5 to 9.7 feet: sand content down, gray and orange swirling, sample came out jumbled auger bit. @ 9.7 to 15.0 feet: silt all brown, some trace gray orange swirls. @ 15.0 to 20.5 feet: silt, all brown, moist.	0	10	90

Depth scale: 5, 10, 15, 20

REMARKS

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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-41U**
LOCATION	**Portland, Oregon**	PAGE	**2 of 2**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**30.0 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/19/14**
GROUND SURFACE ELEVATION	**37.55 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025005**
TOP OF CASING ELEVATION	**40.69 ft C.O.P.**	WATER RESOURCES WELL ID	**L115798**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	1 1 3	1.5/1.5	MC=37.1				**5.7 to 21.5 feet: SILT (ML)**, continued. @ 20.5 to 21.5 feet: sandy silt.	0	10	90
CB	- - -	8.3/10.0		25			**21.5 to 30.0 feet: SILT WITH SAND (ML)**, brown, some fine sand, no plasticity, soft, wet. (ALLUVIUM) @ 27.5 to 30.0 feet: damp silt with sand.	0	20	80
				30 35 40			Total depth: 30.0 feet.			

WELL COMPLETION DETAILS

0 to 17.6 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC blank riser pipe.
17.6 to 27.6 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC well screen with 0.020-inch machined slots.
27.6 to 28.0 feet: Sump.

0 to 2.0 feet: Concrete.
2.0 to 13.0 feet: Granular bentonite.
13.0 to 15.0 feet: Bentonite chips.
15.0 to 28.0 feet: 10-20 Colorado Silica Sand.
28.0 to 30.0 feet: Bentonite chips.

REMARKS

MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	NW Natural GW Source Control	BORING NO.	MW-42F
LOCATION	Portland, Oregon	PAGE	1 of 3
DRILLED BY	Cascade Drilling, Inc., Zone S	LOGGED BY	Ben Johnson
DRILL METHOD	Rotosonic with SPT	TOTAL DEPTH	41.5 ft.
BOREHOLE DIAMETER	4" core barrel, 6" casing	DATE COMPLETED	11/21/14
GROUND SURFACE ELEVATION	33.48 ft C.O.P.	PERMIT/STARTCARD NO.	1025006
TOP OF CASING ELEVATION	36.84 ft C.O.P.	WATER RESOURCES WELL ID	L115799

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	5 23 18	2.5/2.5	MC=7.8 LL=40 PL=30 PI=10		**0 to 2.3 feet: GRAVELLY SAND (SP)**, dark brown, fine sand, fine to coarse, angular to subrounded gravels, loose, damp to dry. (FILL) @ 0.0 to 0.5 foot: silt, sand content down. @ 1.1 to 2.3 feet: lighter brown.	30	65	5
CB	9 11 12	2.5/2.5	MC=5.8		**2.3 to 10.0 feet: SAND (SP)**, brown, medium grained, poorly graded, trace gravel, loose, damp. (FILL)	2	98	0
CB	9 11 11	2.5/2.5	MC=6.1	5				
CB	6 11 14	2.7/2.5	MC=9.8		@ 7.8 to 8.0 feet: large fragmented rock.			
CB	4 6 6	4.9/5.0	MC=10.1	10	**10.0 to 16.4 feet: GRAVELLY SILTY SAND (SW)**, brown with some black, medium sand, fine to coarse gravel, loose, damp. (FILL) @ 12.1 to 12.6 feet: sand (SP), brown, medium grains.	15	60	25
					@ 13.8 to 16.4 feet: silt with sand (ML), silt content up, sand down, brown, no plasticity, trace gravel, loose, damp. (FILL)	5	25	70
CB	6 7 11	5.0/5.0	MC=9.6	15				
					16.4 to 19.1 feet: SAND (SP), brown, medium grained, trace fine gravel, loose, damp. (FILL)	3	97	0
					19.1 to 21.2 feet: GRAVELLY SILTY SAND (SM), description on following page.	10	51	49
				20				

REMARKS
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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	**NW Natural GW Source Control**	BORING NO.	**MW-42F**
LOCATION	**Portland, Oregon**	PAGE	**2 of 3**
DRILLED BY	**Cascade Drilling, Inc., Zone S**	LOGGED BY	**Ben Johnson**
DRILL METHOD	**Rotosonic with SPT**	TOTAL DEPTH	**41.5 ft.**
BOREHOLE DIAMETER	**4" core barrel, 6" casing**	DATE COMPLETED	**11/21/14**
GROUND SURFACE ELEVATION	**33.48 ft C.O.P.**	PERMIT/STARTCARD NO.	**1025006**
TOP OF CASING ELEVATION	**36.84 ft C.O.P.**	WATER RESOURCES WELL ID	**L115799**

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	6 11 21	5.3/5.0	MC=10.9				**19.1 to 21.2 feet: GRAVELLY SILTY SAND (SM)**, brown, medium grained, trace fine gravel, loose, damp. (FILL) @ 19.8 to 21.2 feet: black, hydrocarbon odor, soft, rod pieces in matrix, brick?			
							21.2 to 21.9 feet: SILT WITH SAND (ML), black, no plasticity, trace subrounded gravel, loose, damp, hydrocarbon odor. (FILL)	5	15	80
							21.9 to 31.1 feet: SAND WITH SILT (SP-SM), brown, loose, medium grained sand, trace subrounded gravel, damp. (FILL)	5	80	15
CB	10 14 11	4.8/5.0	MC=12.2	25			@ 22.4 to 22.8 feet: silt (ML), black, hydrocarbon odor. @ 26.4 to 26.7 feet: dry. @ 26.8 to 28.1 feet: black silt veins in matrix. @ 28.3 to 31.1 feet: dark gray sand with silt, medium gravels.			
CB	4 6 4	5.0/5.0	MC=39.6	30						
			MC=11.8 DD=100.3				**31.1 to 36.4 feet: SILT (ML)**, dark gray, low plasticity, soft, damp. (ALLUVIUM)	0	10	90
CB	2 2 1	4.6/5.0	MC=33.5	35			@ 34.8 to 34.9 feet: organic debris.			
							36.4 to 41.5 feet: SANDY SILT (ML), gray, no plasticity, fine grained sand, soft, moist. (ALLUVIUM) @ 37.9 to 38.7 feet: sand (SP), fine grained.	0	35	65
				40						

REMARKS

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ANCHOR QEA

LOG OF EXPLORATORY BORING

PROJECT NAME	NW Natural GW Source Control	BORING NO.	MW-42F
LOCATION	Portland, Oregon	PAGE	3 of 3
DRILLED BY	Cascade Drilling, Inc., Zone S	LOGGED BY	Ben Johnson
DRILL METHOD	Rotosonic with SPT	TOTAL DEPTH	41.5 ft.
BOREHOLE DIAMETER	4" core barrel, 6" casing	DATE COMPLETED	11/21/14
GROUND SURFACE ELEVATION	33.48 ft C.O.P.	PERMIT/STARTCARD NO.	1025006
TOP OF CASING ELEVATION	36.84 ft C.O.P.	WATER RESOURCES WELL ID	L115799

SAMPLING METHOD	SPT COUNT	RECOVERY (FEET)	*LAB RESULTS	DEPTH IN FEET	WELL DETAILS	LITHO-LOGIC COLUMN	LITHOLOGIC DESCRIPTION	GRA %	SAND %	FINES %
CB	4 4 6	1.2/1.5					**36.4 to 41.5 feet: SANDY SILT (ML)**, continued.			
				45 50 55 60			Total depth: 41.5 feet. **WELL COMPLETION DETAILS** 0 to 25.95 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC blank riser pipe. 25.95 to 31.0 feet: 2-inch-diameter, flush-threaded, Schedule 40 PVC well screen with 0.020-inch machined slots. 31.0 to 31.4 feet: Sump. 0 to 3.0 feet: Concrete. 3.0 to 15.0 feet: Granular bentonite. 15.0 to 23.6 feet: Bentonite chips. 23.6 to 31.4 feet: 10-20 Colorado Silica Sand. 31.4 to 41.5 feet: Bentonite chips.			

REMARKS

MC = Moisture Content (%); LL = Liquid Limit (% MC); PL = (% MC); PI=Plasticity Index (% MC); DD = Dry Density (pounds per cubic foot).

ANCHOR QEA

ATTACHMENT B
GEOTECHNICAL LABORATORY REPORTS

Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B • Wilsonville, Oregon 97070 503/682-1880 FAX: 503/682-2753

TECHNICAL REPORT

Report To:	Anchor QEA, LLC 6650 Southwest Redwood Lane, Suite 333 Portland, Oregon 97224	**Date:** **Lab No.:**	1/8/15 14-475
Project:	Laboratory Data – NW Natural Gasco Site	**Project No.:**	2491.1.1

Report of: Moisture content, dry density, Atterberg limits, flexible wall permeability, sieve analysis, and hydrometer sieve analysis

Sample Identification

NTI completed Moisture content, dry density, Atterberg limits, flexible wall permeability, sieve analysis, and hydrometer sieve analysis testing on samples of soil delivered to our laboratory on December 17, 2014. Testing was performed in accordance with the standards indicated. Our laboratory test results are summarized on the following tables and attached pages.

Laboratory Testing

Atterberg Limits (ASTM D4318)			
Sample ID	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**
MW 39F @ 20 - 25 ft.	38	32	6
MW 40F @ 5.0 - 7.5 ft.	33	20	13
MW 42F @ 30 - 35 ft.	40	30	10
AQB8 @ 35 - 40 ft.	37	27	10
AQB8 @ 40 - 45 ft.	36	30	6

Moisture Content of Soil and Dry Density (ASTM D2216/D2937)		
Sample ID	**Moisture Content (Percent)**	**Dry Density (pcf)**
MW 42F @ 31 – 31.5 ft.	11.8	100.3

Attachments: Laboratory Test Results

Copies: Addressee

Northwest Testing, Inc.
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TECHNICAL REPORT

Report To: Anchor QEA, LLC
6650 Southwest Redwood Lane, Suite 333
Portland, Oregon 97224

Date: 1/8/15

Lab No.: 14-475

Project: Laboratory Data – NW Natural Gasco Site

Project No.: 2491.1.1

Laboratory Testing

Moisture Content of Soil (ASTM D2216)			
Sample ID	**Moisture Content (Percent)**	**Sample ID**	**Moisture Content (Percent)**
MW 39F @ 0.0 – 2.5 ft.	17.5	MW 42F @ 0 - 2.5 ft.	7.8
MW 39F @ 2.5 – 5.0 ft.	10.5	MW 42F @ 2.5 – 5.0 ft.	5.8
MW 39F @ 5.0 - 7.5 ft.	17.1	MW 42F @ 5.0 - 7.5 ft.	6.1
MW 39F @ 7.5 – 10 ft.	16.1	MW 42F @ 7.5 - 10 ft.	9.8
MW 39F @ 10 – 15 ft.	18.8	MW 42F @ 10 - 15 ft.	10.1
MW 39F @ 15 – 20 ft.	47.7	MW 42F @ 15 - 20 ft.	9.6
MW 39F @ 20 - 25 ft.	38.8	MW 42F @ 20 - 25 ft.	10.9
MW 40F @ 0.0 – 2.5	11.8	MW 42F @ 25 - 30 ft.	12.2
MW 40F @ 2.5 - 5.0 ft.	16.5	MW 42F @ 30 - 35 ft.	39.6
MW 40F @ 5.0 - 7.5 ft.	17.8	MW 42F @ 35 - 40 ft.	33.5
MW 40F @ 10 - 15 ft.	25.4	AQB8 @ 0.0 – 2.5 ft.	11.2
MW 40F @ 15 - 20 ft.	18.7	AQB8 @ 2.5 - 5.0 ft.	10.1
MW 40F @ 20 - 25 ft.	22.9	AQB8 @ 5.0 – 7.5 ft.	9.3
MW 40F @ 25 - 30 ft.	44.3	AQB8 @ 7.5 - 10 ft.	9.4
MW 40F @ 30 - 35 ft.	39.6	AQB8 @ 10 - 15 ft	12.4
MW 41F @ 0.0 – 2.5 ft.	19.9	AQB8 @ 15 - 20 ft.	12.4
MW 41F @ 2.5 - 5 ft.	11.6	AQB8 @ 20 - 25 ft.	10.1
MW 41F @ 5.0 – 7.5 ft.	27.4	AQB8 @ 25 - 30 ft.	8.8
MW 41F @ 7.5 - 10 ft.	29.2	AQB8 @ 30 - 35 ft.	29.8
MW 41F @ 10 - 15 ft.	33.7	AQB8 @ 35 - 40 ft.	39.0
MW 41F @ 15 - 20 ft.	35.7	AQB8 @ 40 - 45 ft.	37.1
MW 41F @ 20 - 25 ft.	37.1		

 REVIEWED BY: Bridgett Adame

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TECHNICAL REPORT

Report To: Anchor QEA, LLC
6650 Southwest Redwood Lane, Suite 333
Portland, Oregon 97224

Date: 1/8/15

Lab No.: 14-475

Project: Laboratory Data – NW Natural Gasco Site

Project No.: 2491.1.1

Laboratory Test Results

Particle Size Analysis of Soils (ASTM D422)				
Sieve Size	**MW 40F @ 2.5 - 5.0 ft. Percent Passing**	**MW 40F @ 10 - 15 ft. Percent Passing**	**MW 40F @ 25 - 30 ft. Percent Passing**	**MW 42F @ 0 – 2.5 ft. Percent Passing**
1"	100	100	100	100
¾"	99	100	100	98
½"	89	96	100	96
⅜"	83	92	100	94
¼"	77	91	100	86
#4	74	88	100	80
#8	68	85	100	67
#10	67	84	100	64
#16	63	82	100	57
#30	55	79	99	45
#40	45	73	78	35
#50	33	60	62	26
#100	21	47	44	19
#200	15.4	34.7	32.8	14.9

Particle Size Analysis of Soils (ASTM D422)				
Sieve Size	**MW 42F @ 7.5 - 10 ft. Percent Passing**	**MW 42F @ 30 - 35 ft. Percent Passing**	**AQB8 @ 2.5 - 5 ft. Percent Passing**	**AQB8 @ 25 – 30 ft. Percent Passing**
¾"	100	100	100	100
½"	99	100	99	100
⅜"	98	99	99	100
¼"	97	97	99	98
#4	96	97	99	97
#8	95	96	97	94
#10	94	96	97	93
#16	92	95	95	90
#30	80	94	83	65
#40	59	92	61	39
#50	30	90	28	19
#100	14	80	9	10
#200	10.7	57.4	6.8	7.4

REVIEWED BY: Bridgett Adame

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TECHNICAL REPORT

Report To:	Anchor QEA, LLC 6650 Southwest Redwood Lane, Suite 333 Portland, Oregon 97224	**Date:** **Lab No.:**	1/8/15 14-475
Project:	Laboratory Data – NW Natural Gasco Site	**Project No.:**	2491.1.1

Laboratory Test Results

Sample Description: MW40F @ 26.5 – 29 ft.

Flexible Wall Permeability – Sample Data (ASTM D5084 – Method C)					
Mass (grams)	**Length (inches)**	**Diameter (inches)**	**Area (sq. inches)**	**Moisture Content (percent)**	**Dry Density (pcf)**
315.0	1.770	2.851	6.384	52.3	69.7

Flexible Wall Permeability – Test Data (ASTM D5084 – Method C)				
Sample Condition	**Saturation at Time of Testing (percent)**	**Confining Pressure at Time of Testing (psi)**	**Head (psi)**	**Hydraulic Gradient (in/in)**
Undisturbed	98	30.0	1.0	16.16

Flexible Wall Permeability – Test Results (ASTM D5084 – Method C)				
Test 1 k (cm/sec)	**Test 2 k (cm/sec)**	**Test 3 k (cm/sec)**	**Test 4 k (cm/sec)**	**Average k (cm/sec)**
6.37×10^{-8}	6.91×10^{-8}	6.29×10^{-8}	6.65×10^{-8}	6.56×10^{-8}

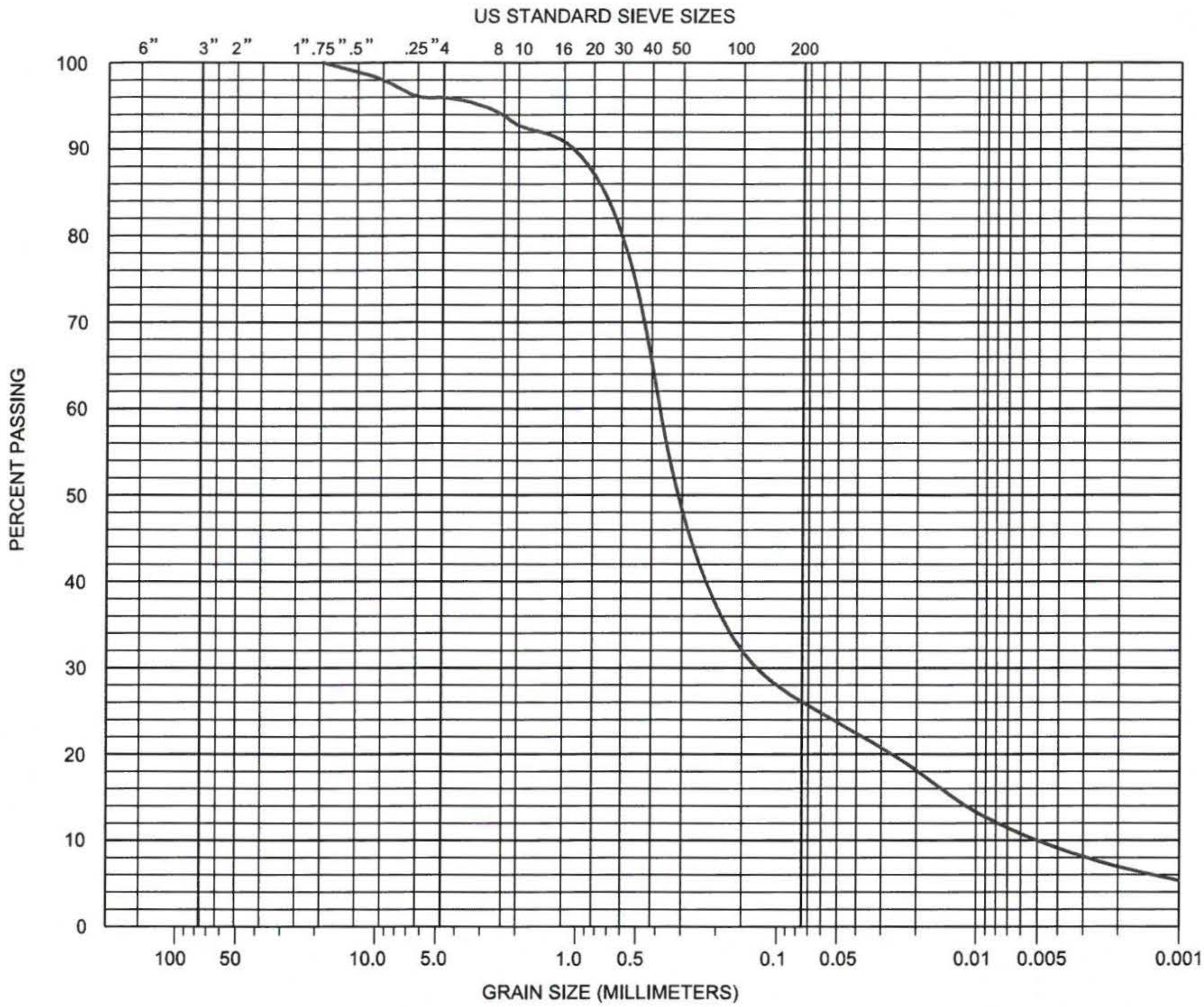
Sample Description: MW42F @ 31 – 33.5 ft.

Flexible Wall Permeability – Sample Data (ASTM D5084 – Method C)					
Mass (grams)	**Length (inches)**	**Diameter (inches)**	**Area (sq. inches)**	**Moisture Content (percent)**	**Dry Density (pcf)**
264.8	1.420	2.855	6.403	37.9	80.5

Flexible Wall Permeability – Test Data (ASTM D5084 – Method C)				
Sample Condition	**Saturation at Time of Testing (percent)**	**Confining Pressure at Time of Testing (psi)**	**Head (psi)**	**Hydraulic Gradient (in/in)**
Undisturbed	99	40.0	1.0	20.15

Flexible Wall Permeability – Test Results (ASTM D5084 – Method C)				
Test 1 k (cm/sec)	**Test 2 k (cm/sec)**	**Test 3 k (cm/sec)**	**Test 4 k (cm/sec)**	**Average k (cm/sec)**
5.47×10^{-7}	5.39×10^{-7}	5.09×10^{-7}	5.28×10^{-7}	5.31×10^{-7}

 REVIEWED BY: Bridgett Adame

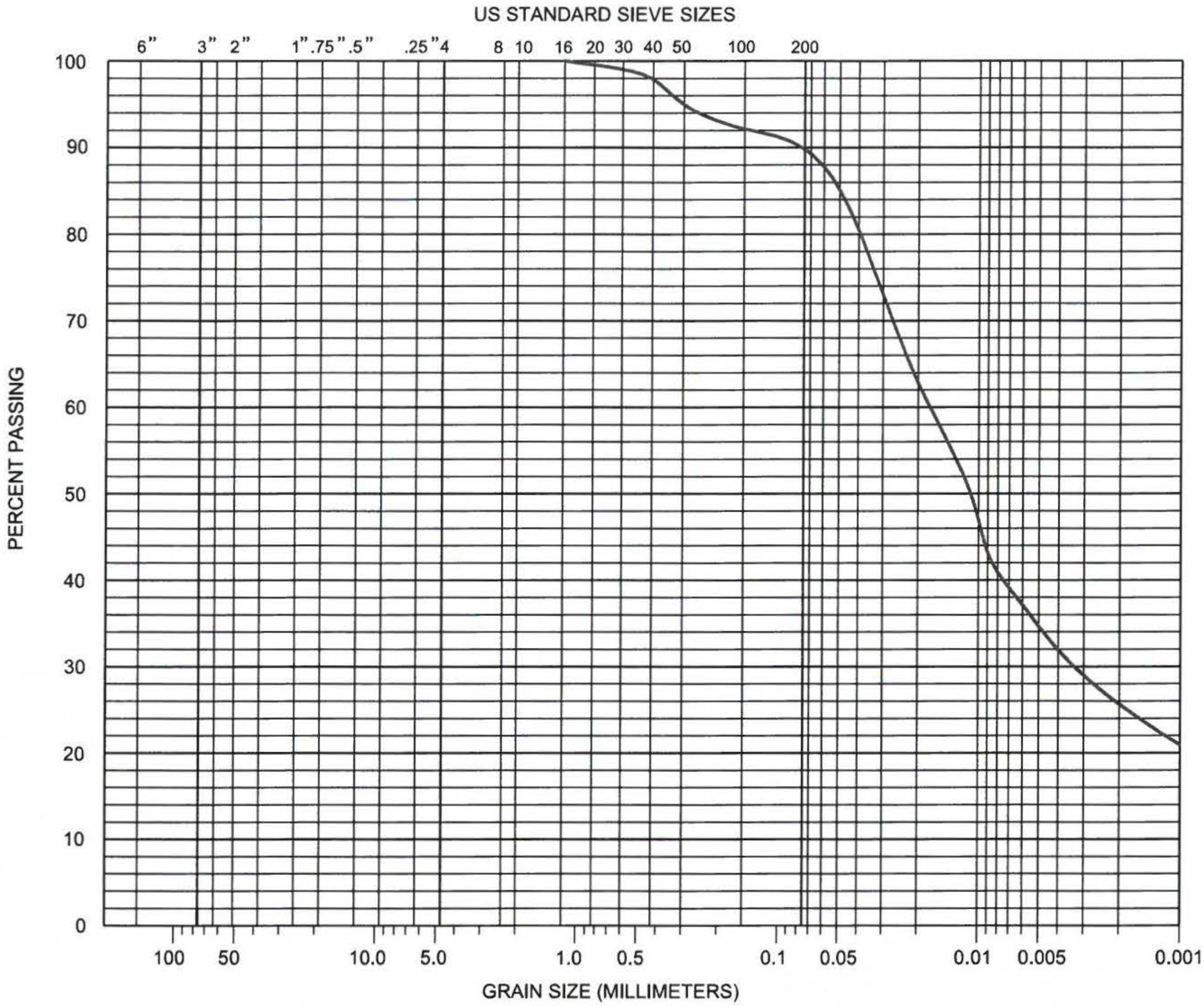


COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING $2\ \mu$	UNIFIED SOIL CLASSIFICATION
———	MW42F @ 20-25 FT.	--	26	7	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2491.1.1	ANCHOR QEA LABORATORY TESTING	LAB NO. 14-475



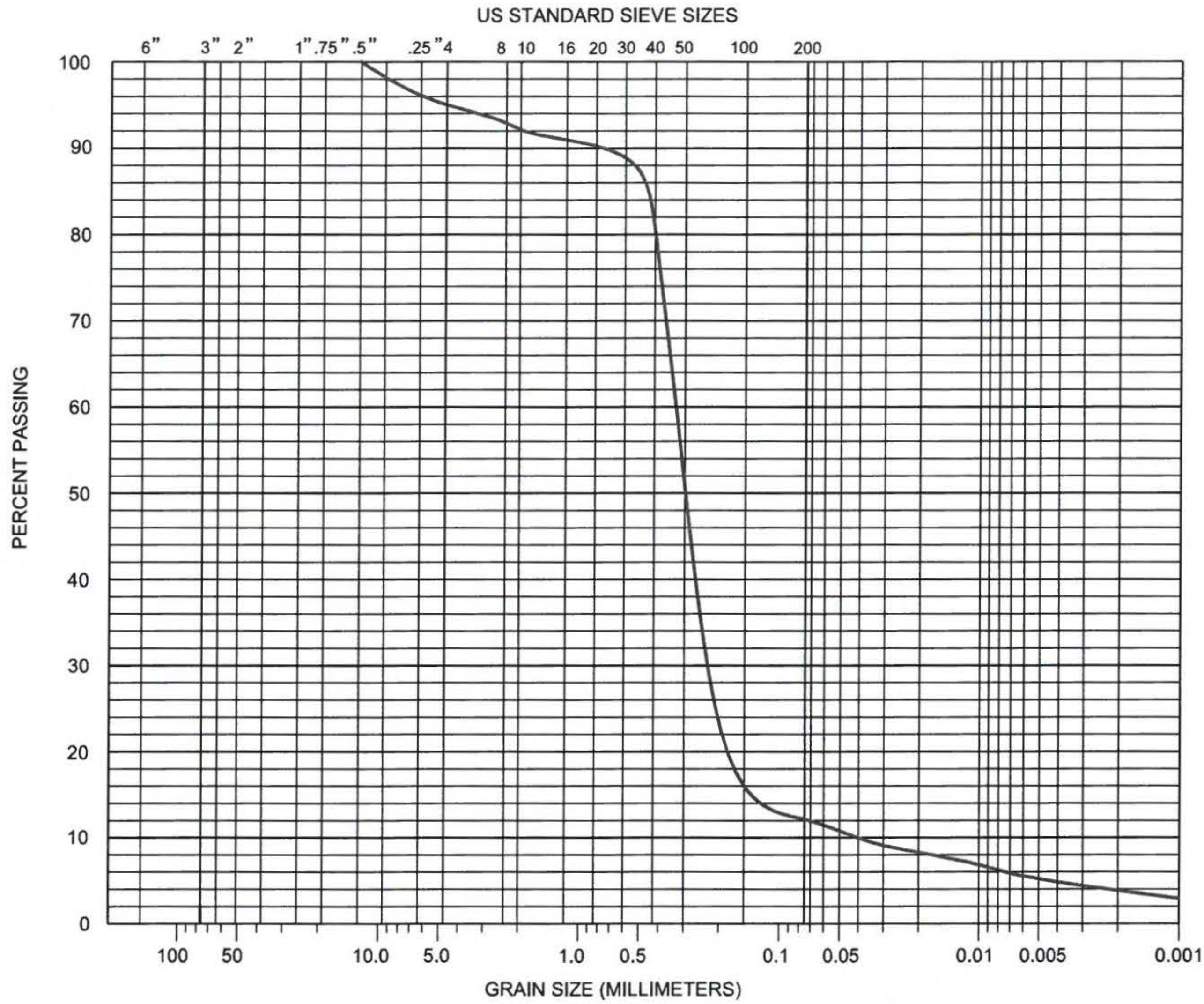
COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 µ	UNIFIED SOIL CLASSIFICATION
———	MW41F @ 10-15 FT.	--	90	26	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2491.1.1	ANCHOR QEA LABORATORY TESTING	LAB NO. 14-475

Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.

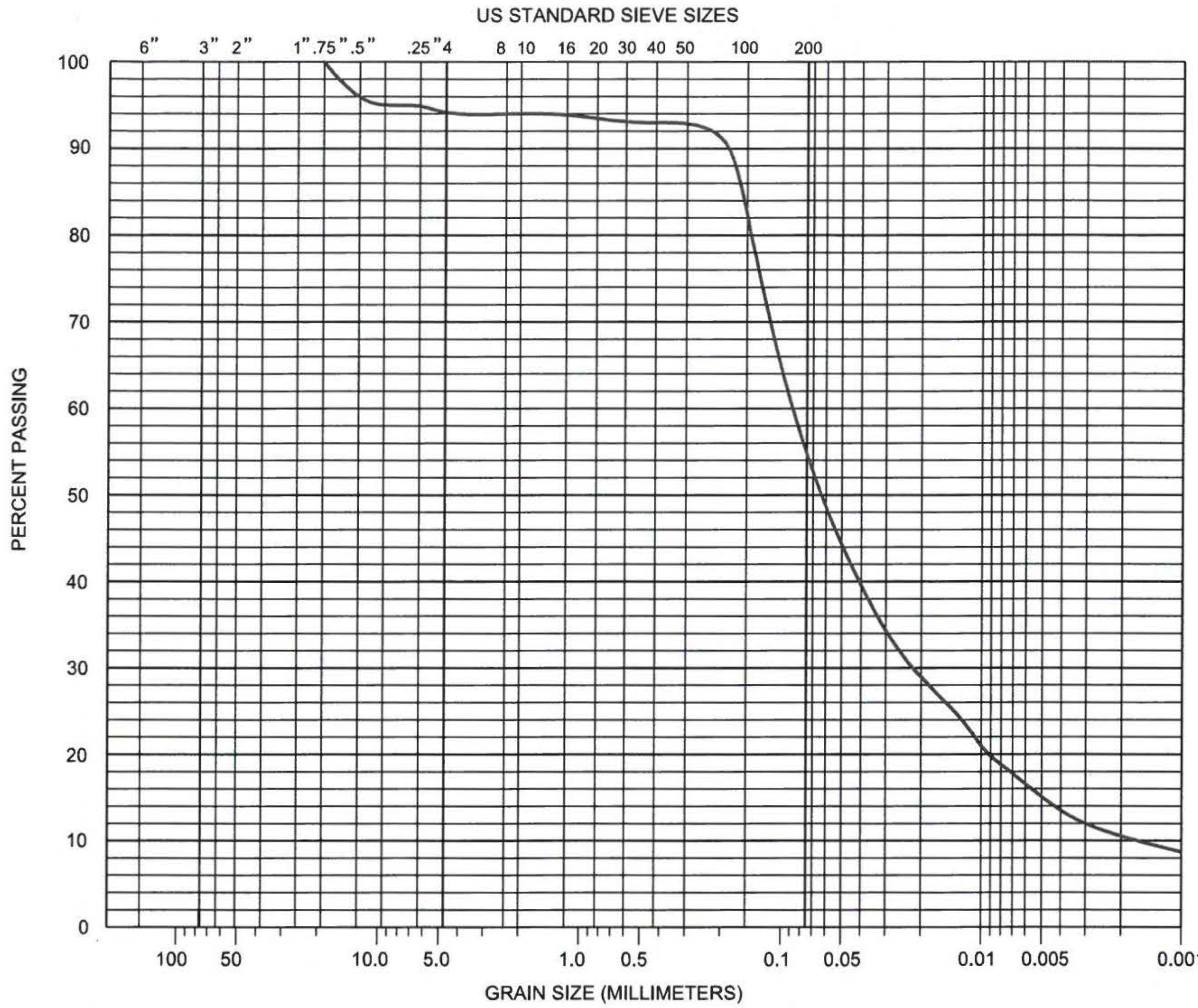


COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 μ	UNIFIED SOIL CLASSIFICATION
———	MW41F @ 2.5-5.0 FT.	--	12	4	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2491.1.1	ANCHOR QEA LABORATORY TESTING	LAB NO. 14-475



COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 μ	UNIFIED SOIL CLASSIFICATION
———	MW39F @ 20-25 FT.	--	55	10.5	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2491.1.1	ANCHOR QEA LABORATORY TESTING	LAB NO. 14-475

Northwest Testing, Inc.
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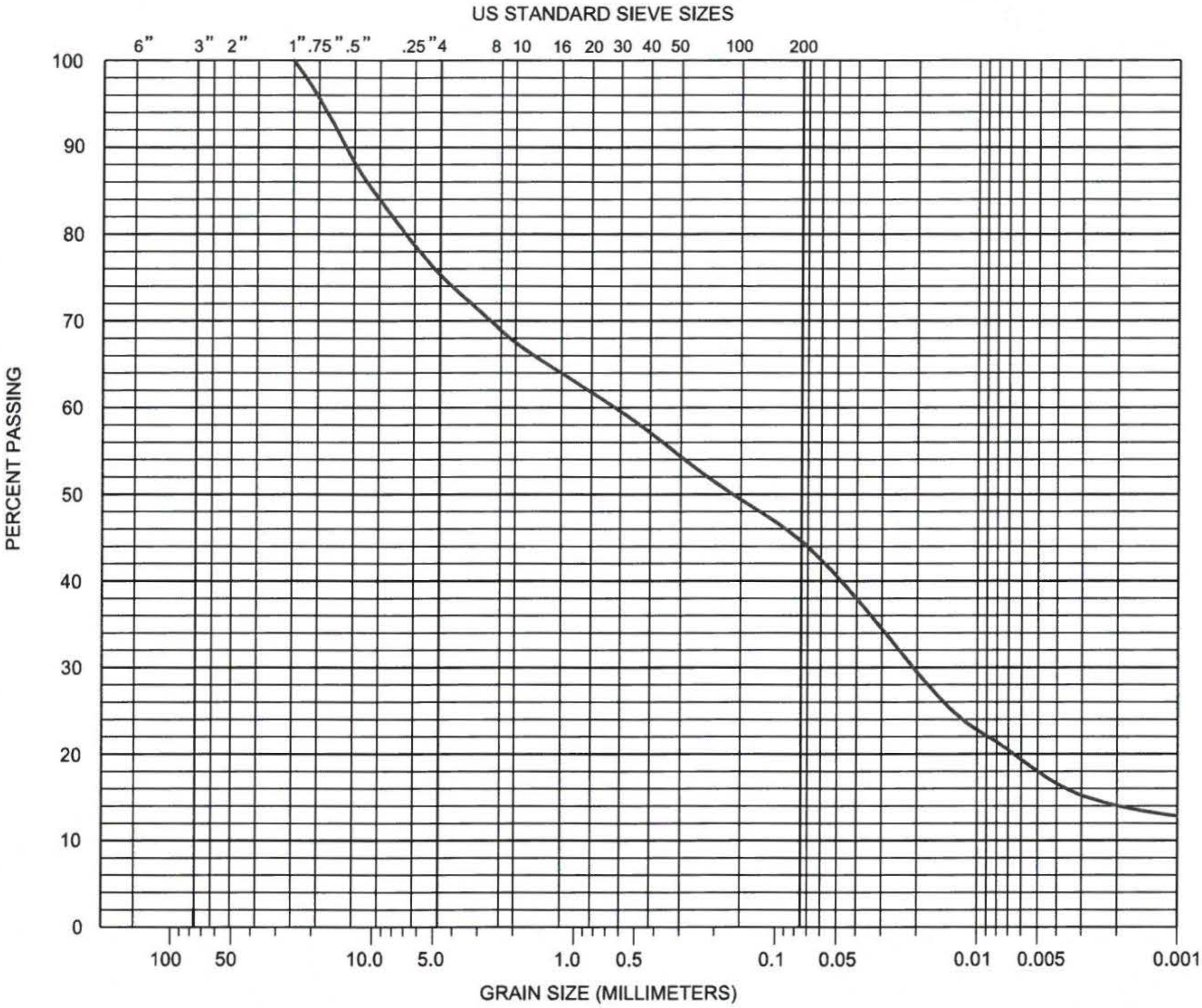

COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 μ	UNIFIED SOIL CLASSIFICATION
———	MW39F @ 5.0-7.5 FT.	--	45	14	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2491.1.1	ANCHOR QEA LABORATORY TESTING	LAB NO. 14-475

Northwest Testing, Inc.
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